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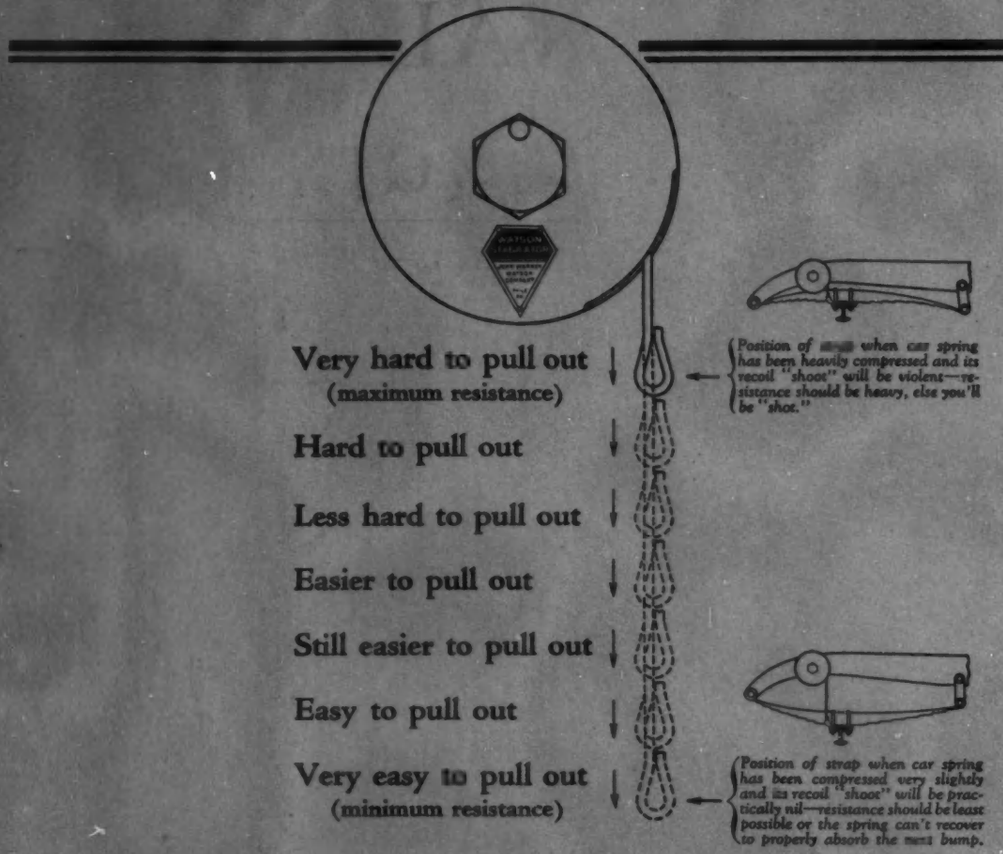
THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

SEPTEMBER 1923

SOCIETY OF AUTOMOTIVE ENGINEERS INC.
29 WEST 39TH STREET NEW YORK

Have You Ever Made This Test?

Clamp any recoil check in a vise, brace your foot up against the bench, and then tug on the strap. According to whether the strap offers less and less resistance or more and more resistance as you continue to pull it out you can tell whether the device is right or wrong.


Very hard to pull out
(maximum resistance)
Hard to pull out
Less hard to pull out
Easier to pull out
Still easier to pull out
Easy to pull out
Very easy to pull out
(minimum resistance)
Position of strap when car spring has been heavily compressed and its recoil "shoot" will be violent—resistance should be heavy, else you'll be "shot."
Position of strap when car spring has been compressed very slightly and its recoil "shoot" will be practically nil—resistance should be least possible or the spring can't recover to properly absorb the next bump.

YOU will find that a STABILATOR strap, as illustrated herewith, offers very stubborn resistance at the *beginning* of the pull and gradually resists less and less as you keep pulling it out. Thus a STABILATOR is not, in effect, a jump strap, but is a brake which automatically resists heaviest when the car spring is fully compressed and its recoil force is most violent—and resists less and less accordingly as the recoil force is *less* violent.

This resisting of each varying recoil force in *proportion* to that force is nothing more than an adherence to the same logic which tells us to put small brakes on the wheels of a Ford car and very large and powerful brakes on the wheels of a Mack 5-ton truck.

You need not take anyone's "say so" as to whether or not this, that or the other device offers correct, proportional resistance to the varying forces of spring recoil—just clamp the thing in a vise, tug on the strap, and *know* what it gives.

JOHN WARREN WATSON COMPANY, PHILADELPHIA
Twenty-fourth and Locust Streets

WATSON STABILATORS

Change the Whole Nature of Your Car

THE

JOURNAL
OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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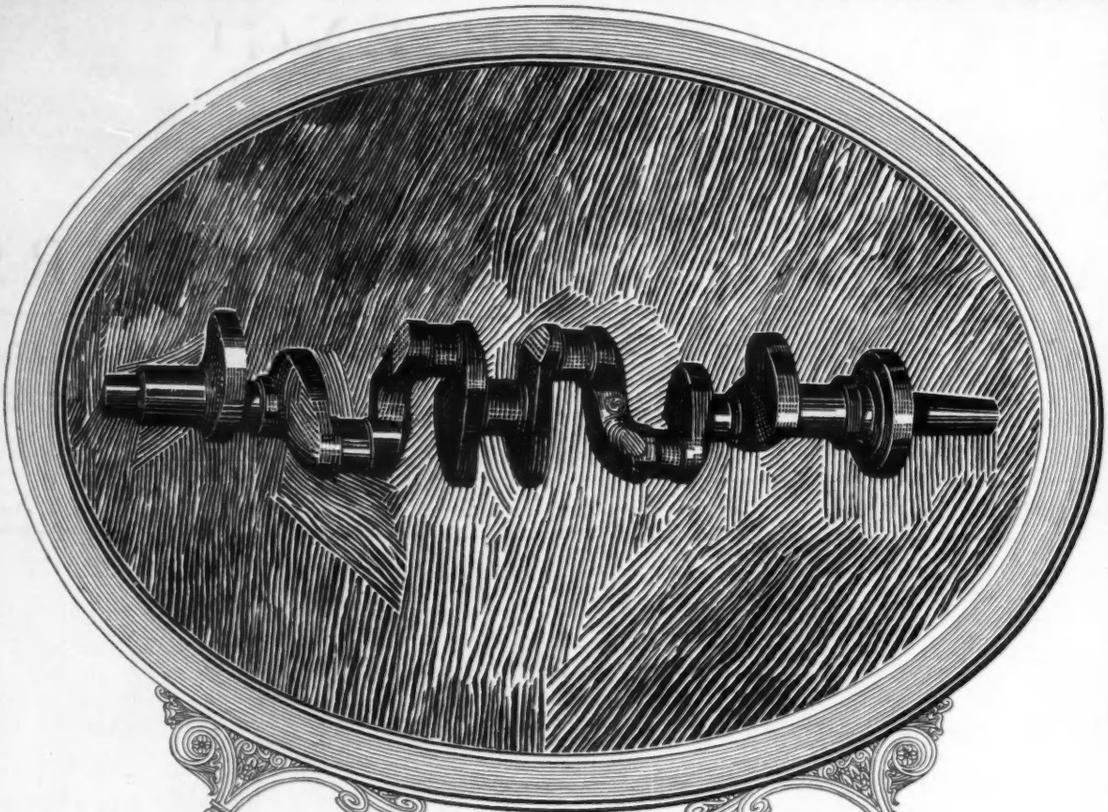

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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chronicle and Comment

Letter Ballot on Standards

As a result of the Society letter ballot on the adoption of standards, the recommendations approved at the Standards Committee Meeting at Spring Lake were confirmed and have been issued to the members in final data-sheet form. The results of the letter ballot are given on p. 246.

Annual Meeting Date Announced

ANNOUNCEMENT was made last spring that the next Annual Meeting of the Society would be held in Detroit. The dates of this meeting have now been set definitely as Jan. 22-25 to coincide with Automobile Show week in Detroit. This arrangement will enable members who attend the meeting to inspect passenger cars and trucks of the latest design, many of which will come direct from the New York Show on the way to Chicago. Thus the advantage of holding the Annual Meeting simultaneously with a representative exhibit of motor vehicles will be preserved, conflicts with numerous dealer, factory and association functions will be avoided, and the location of the meeting will be nearer the production center of the industry.

International Ball Bearing Standards

A RECENT report received from Zurich, Switzerland, indicates that considerable progress was made at the International Conference of Secretaries of national standardizing bodies held there on July 9 toward the international standardization of ball bearings, particularly the radial type. The Zurich conference on ball bearings was attended by the Secretaries of the Swiss, Swedish, German and American national standardization bodies and by delegates of Swedish, German and American Sectional Committees.

Although the report is preliminary only, it indicates that those attending the conference agreed upon the diameters, widths, and corner radii for radial type bearings in light, medium and heavy series. If the extra wide type of radial bearings is needed by the foreign countries, the S. A. E. Standards will be considered. A proposal is to be prepared for tolerances for bores, diameters and widths based on the unilateral system, the bore and diameter tolerances following approximately those proposed by the American Sectional Committee in March, 1922, and the width tolerances following the present Swedish practice.

The latest German proposal for thrust ball bearings was recommended, extended to include 600 mm. diameter and an extra heavy series, the tolerances for all diameters to follow those for the radial bearings. The Sectional Committees of England and America are asked to submit proposals for inch size bearings.

Pennsylvania License Law Unconstitutional

AN opinion that the Pennsylvania engineering licensing act is unconstitutional has been rendered by a judge in the Court of Quarter Sessions of Monroe County of that State. The judge interpreted the law as conflicting with the constitution of the State on the technicality that it deals with two professions in the same act, a condition forbidden by the State constitution. He also contended that the licensing act violated the Fourteenth Amendment of the Federal Constitution in that it shows discrimination in the exemption of certain classes. This action will be of interest to members of the Society who practise in the State of Pennsylvania, and may also be expected to influence legislation and the enforcement of laws in other States in which similar statutes are contemplated or are already in force.

Keeping Pace with Progress

SECTION meetings activity reopens with the arrival of September and the fall season. A calendar of the meetings scheduled during the coming month will be found on p. 252. Eight-in-line engines, headlamp glare and wheel-alignment are the topics to be discussed by three of the Sections, the members of one of the other Sections will visit a large passenger-car factory and another Section opens its session with sports and a social evening.

Meetings of the Sections have gained in value and importance with the expansion of the parent Society. Attendance is often as large as at the national technical sessions; papers presented have equal status with those read at the parent Society meetings and receive the same consideration in THE JOURNAL. Discussion at Section meetings is especially productive of valuable information because of the presence of a larger group of specialists at the local meetings and the longer discussion period

that is usually available. Section meetings broaden one's acquaintance and viewpoint; they are the equivalent of a series of post-graduate lectures in automotive engineering. Form the habit of attending them and you will derive full value from your membership in the Society.

Promoting Production Efficiency

MACHINE tools and production methods that are of particular interest to manufacturing executives will be discussed at the Production Meeting of the Society in Cleveland next October. This meeting is intended to serve as a national clearing-house where factory managers may exchange ideas regarding valuable shop experience and discuss production problems to their common benefit and for the general good of the industry. Over 500 production men took advantage of the opportunity offered by the meeting in Detroit last October and voiced their approval of it as a means of perpetuating the cooperative spirit among factory experts that was engendered by the war. Shop kinks used to be guarded jealously by their originators, but the national emergency destroyed that selfish attitude. Exchange of practical shop information is now fairly universal and the Production Meeting merely fosters this exchange to a greater degree and on an organized basis. If you have material that you wish to place before the Cleveland meeting be sure to call it to the attention of the New York Office at once. Do not fail to mark the dates on your calendar and come to Cleveland Oct. 25 and 26.

Standards Committee Meetings

MEETINGS of Divisions and Subdivisions of the Standards Committee are being planned to start about the middle of September in most cases, according to the progress that is made with the work before each group. The time and place of all meetings will be arranged so far as possible so that all Division and Subdivision members can attend with the least expense and time. Regular notices will be sent to all members sufficiently in advance of meetings so that they can arrange accordingly.

It is expected meetings will be arranged for the Axle and Wheels, Ball and Roller Bearings, Electric Vehicle, Engine, Lighting, Lubricants, Passenger-Car Body, Screw Threads, Tire and Rim, and Transmission Divisions. A meeting of the Motorboat Division has already been scheduled at the Society's Offices in New York City on Thursday, Sept. 27, at 2 o'clock.

Better Brakes Assured

REGARDLESS of the many derogatory comments that have been made on four-wheel brakes, their introduction is producing one commendable result. It is stimulating engineering investigation that eventually will increase the effectiveness of brakes in general. Practically as much thought is being expended on rear-wheel and transmission brakes as on the perfecting of satisfactory four-wheel systems. Deceleration is now becoming as important in comparisons of performance as acceleration has been in the past. It is fortunate that this attitude should prevail at a time when public opinion is stirred by the rising number of deplorable automobile accidents. Careless and irresponsible drivers are beyond the influence of the automotive engineer, but he can contribute to the reduction of accidents by providing motor cars with means of deceleration that at least are as highly developed as those of acceleration. This he appears to be doing, and the introduction of four-wheel brakes deserves a large share of the credit for stimulating his interest in this phase of highway safety work.

Agitation for compulsory periodic brake-inspection has began in many parts of the Country. Whether such measures will conduce to greater safety lies outside the province of this comment, but they do serve as a warning to automotive engineers that inefficient braking systems will not be acceptable to the motor-buying public in the future. Operators will pay more attention to ease of adjustment and equalization. Narrow linings, which wear rapidly and need to be replaced frequently, will be decidedly unpopular; inaccessible adjustments of linkage and bands will be condemned. Efficient brakes that can be kept efficient with the minimum of attention will be an important factor in influencing motorists in their selection of 1924 models.

1922 Transactions

WHEN this issue of THE JOURNAL went to press Part I of the 1922 TRANSACTIONS was in the hands of the binder, and it is expected that copies will be sent the latter part of this month to those of the members who have requested them. This part, which is the first of Vol. 17 of THE TRANSACTIONS, is a book of approximately 920 pp. and contains such of the papers presented at the 1922 Annual Meeting of the Society, together with those of the papers presented at Section meetings and printed in THE JOURNAL for the first 6 months of last year, as were deemed of sufficient engineering value by the Publication Committee to be reprinted in the permanent records of the Society.

Following the arrangement that was first used in Part II of the 1921 TRANSACTIONS, the 31 papers constituting the present volume are grouped according to subjects irrespective of where the papers were presented instead of following the earlier arrangement in which the papers at the National meetings of the Society came first, with the Section papers following according to the alphabetical arrangement of the names of the Sections. The subjects covered include fuels and engines, lubrication, the development of air-cooled cylinders and engines, testing brake-linings, tractors, metallurgical subjects, body design and dimensions and roads and highways. To supplement the information presented in the various papers, numerous illustrations have been used and in several instances folding inserts have been employed where it was impossible to reduce tables or illustrations to the size of THE TRANSACTIONS' page without considerably impairing their value.

Work on Part II of the 1922 TRANSACTIONS has already been begun and the date for the appearance of this volume has been tentatively set as Dec. 31, 1923. Copies of this part will be sent only to members who send in their orders by Nov. 5. There is no charge for this volume to members who paid dues for the first half of the fiscal year beginning Oct. 1, 1922. For the convenience of the members in ordering this part of THE TRANSACTIONS, an order blank will be found in the advertising section of this issue on p. 83.

Vol. XIII September, 1923 No. 3

Trolley Buses and Flexible Vehicles for Street Railway Service

By William P. Kennedy[1]

Metropolitan Section Paper *Illustrated with* Photographs and Drawings

THE author surveys some of the general conditions prevailing in the street-railway field and the prospective development of a new type of service, in discussing the necessity for closer cooperation between the engineers of the automotive industry and the operating organizations of the railways, the idea being to develop flexible transportation-equipment that will coordinate with the operation of present railway-transportation facilities and to promote the utilization, wherever feasible, of railway power-supply in the employment of flexible bus-type equipment in supplementing and extending railway-organization service.

Changing conditions are outlined, the influences tending toward flexible equipment are stated, and the differences of engineering practice pertaining in the railway and automotive fields are commented upon to show wherein railway and automotive engineers can cooperate.

The trolley bus is considered in some detail as being one solution of the problem, and the Mercedes Stoll, the Filovia and the Max Schiemann systems of operation are described. Present national practices of operation with various types of equipment are mentioned, and a description of dual-power bus-equipment and independent buses having electrical transmissions, with comment thereon, is included. Body and chassis requirements are enumerated, the permanency of public-service transportation and prospective street-railway business is considered, and the requirements of so-called "flexible" equipment are treated at length.

THE general purpose of this paper is to make evident the necessity for closer cooperation between the engineers of the automotive industry and the operating organizations in the street-railway field, with the idea of solving more effectively the particular problems of the latter in their endeavor to develop flexible transportation-equipment to coordinate with the operation of their rail-transportation facilities and further, to promote the utilization wherever feasible of railway power-supply in the employment of flexible bus-type equipment in supplementing and extending railway-organization service. It is necessary, therefore, to survey some of the general conditions prevailing in the street-railway field, and the prospective development of a new type of service within the near future.

Changing Conditions

In 30 to 40 years of development of power-operated street-railway passenger-transportation equipment, there has been gradual progress in meeting a constantly increasing demand from the earlier lighter types of vehicle and rail equipment, inherited from the preceding horse-car service, to the more capacious forms of equipment required for mass transportation in densely populated cities, and the collateral development of the heavier long-distance Pullman-type vehicles used in interurban service. During the greater period of this progress, there has been a constant increase in the weight of equipment employed. In recent years, however, there has been a marked endeavor to reduce these weights in view of the improvement in structural materials, developed largely by the demands of the automotive industry. This recession has been forced by the changing economic conditions affecting the cost of operation and, more recently, by the appearance of competition in the field in the form of the motorbus.

When we review in perspective the various developments that have taken place in public-service utilities over a period of 50 years or more, we are able to realize the relative stability of each division of these utilities and thus to form sound judgment as to the permanency of their foundation, particularly in the equipment employed in each of these divisions, which are railroad freight and passenger service, public lighting, the generation and distribution of energy for power purposes and street-railway systems for local passenger-transportation. The permanency of these several industries depends largely upon the invention and application of devices that tend to expand their application territorially, or that supply the public with means facilitating a more broad utilization of the service rendered. This implies an urgent necessity on the part of public-service organizations to foster and to develop the employment of such devices. On the other hand, the instability of these public utilities can be measured by the likelihood of the growth of competitive developments in the form of devices that can be procured by competitive operators and employed with much less investment and that may render a somewhat similar if not equivalent service to the user.

In such a comparison it will be realized that long-distance railroad-service as a public utility is almost impregnable, and that public-lighting utilities are so substantially entrenched and can be operated so economically that competition is negligible. Power generation and distribution on a large scale, as yet in its early stages, is similarly on a secure foundation; and it may be observed that the lighting and power industries have been developed and will continue to progress under the conditions of competition that have been the means of keeping them in an aggressively active condition.

Influences Tending Toward Flexible Equipment

In contrast with the foregoing statements, the street-railway industry has grown up under the fallacious belief that it is equally as stable as the railroad industry, and the development of its equipment seems to have progressed with the absence of any thought of possible competition. Unfortunately, its permanency is much more dependent upon a number of isolated and local conditions, being subject to political and community requirements, and monopolizing to a large extent the public

[1] M.S.A.E.—President, Kennedy Engineering Corporation, New York City.

thoroughfares that are in demand for use by others with different purposes. It was not recognized until a few years ago that a number of influences were growing up which would not only generate competition, but seriously threaten their existence in many localities. Of these influences, two are particularly conspicuous; one is the development of public vehicles in the form of the automobile, capable of rendering competing service in the hands of independent operators, and the other the influence on public opinion of the private use of the automobile in creating a demand for a different kind of public service.

If the street-railway utilities had been developed in a competitive atmosphere similar to the conditions under which light and power distribution have been developed, they would have been in a more elastic position to adjust themselves to any condition of change; but, having an inborn assurance of permanency, the intrusion of competition into their immediate field has found them in an attitude of resistance instead of flexibility to offset this with the use of equipment designed and applied to overcome opposition. This attitude of self assurance, combined with the natural handicaps existing in their mode of operation, such as rigidity of rail service impeding change in routes or location, inflexibility of equipment, increasing danger to passengers due to increasing traffic in boarding and alighting from this equipment and the enforced economies acting as irritants, such as increasing fares and limitations of transfers, have aided the public's general disposition to favor the more flexible service offered in bus transportation. The inclination to prefer the motorbus has been fostered by the public's increasing familiarity with the comfort and convenience of automobile transportation. This situation, and particularly the attitude of the street-railway organizations, must necessarily have a temporary existence as, ultimately, public transportation must certainly remain in the hands of those organizations that are qualified by their position, experience and the necessity for continued existence to render public service, modified wherever necessary to meet changing demands.

There is little question as to street-railway-organization permanency along existing lines in rendering mass-transportation service in thickly populated districts, but changes in equipment and mode of service will be urgently demanded in other localities. It is equally reasonable to assume that these organizations will shortly prepare to provide for these essential changes in the direction of employing automotive-type equipment, and it is in these activities that there is a necessity for closer cooperation between the engineers of the automotive industry and those of the railway industry.

Differences of Engineering Practice

An illuminating picture of the increasing weight of street-car equipment up to vehicles weighing 80,000 lb., and the recent replacement of these by vehicles weighing 35,000 lb. for rendering equivalent service with very much reduced operating cost, appears in an article by C. T. Dehore, entitled Light-Weight Interurban Cars.[2]

This article shows that street-railway engineering followed a line in which the weight of the equipment and the cost of its operation were not so economically important as they have recently become and that, in the past, railway engineers were not forced to use the stronger and lighter materials necessitated by the competition in design and manufacture that has been the soul of the automotive industry, tending to produce vehicles of a minimum weight for a maximum performance. The automobile is a power vehicle exemplifying characteristics in marked contrast with the street car that was developed for an entirely different service when the number of passengers and the speed of the machine are taken into consideration. Nevertheless, the fact is apparent that the changing demand in public passenger-transportation encourages a closer cooperation between the two schools of engineering thought existing in these different fields to combine in developing the best that can be procured to meet these new requirements.

The railway engineer has been handicapped from a progressive standpoint by the absence of the necessity of meeting competition. There has been a comparatively limited output in machines for his industry, reducing the possibility of mass production; consequently and of necessity, there have been limited sources from which he could procure competitively developed equipment. His power units came from two or three large manufacturing organizations providing other varied products, which naturally limited any tendency to progress rapidly toward lighter and more flexible machines. Likewise, his sources of body structures were limited and confined to comparatively few manufacturers, with the obvious handicaps that changes from previously established standards were difficult to obtain. Furthermore, the necessity for caution in providing against accident and damage in rendering public service enforced upon him a conservatism from which the automotive engineer has been almost entirely free; obviously, it must be recognized that a readiness to rise up quickly and provide radically different forms of vehicles to meet emergencies in offsetting unforeseen competition was not to be expected. Now, however, after a period in which competing types of vehicle in the form of motorbuses have been permitted to intrude upon his business field, with the consequent loss of the most easily secured and profitable part of his sources of revenue, his attitude must necessarily change and he must proceed at once to provide an acceptable solution in a new form of equipment to enable his industry not only to recover its lost business but to reach into new fields for expansion and profit.

Railway and Automotive Cooperation

He cannot be expected to be entirely familiar with all of the new equipment available to him of which he might make use, nor has he had experience in the use of such new equipment as will enable him to provide safely for the contingencies that are inherent to public-service passenger-transportation. On the other hand, while the automotive engineer may be entirely familiar with the variety of forms and possible uses of the mechanical and power units that have been developed within his field, he has not acquired by experience any complete knowledge of the service demands to which such mechanical and power units may be subjected under the arduous services required in rendering the continuous performance demanded in public-utility service. Hence, there is good reason for a give-and-take attitude in the meeting of these different minds when concentrated in common upon the new problems in question, and it must be conceded that such an intimate collaboration would certainly be productive of advantage to the industries represented by both parties.

The particular fundamental fact to be borne in mind is that the vehicles which would best serve these purposes would be those that could utilize partly, if not entirely, the power-supply and distribution system available for such employment existing within the street-

[2] See *General Electric Review*, June, 1922, p. 352.

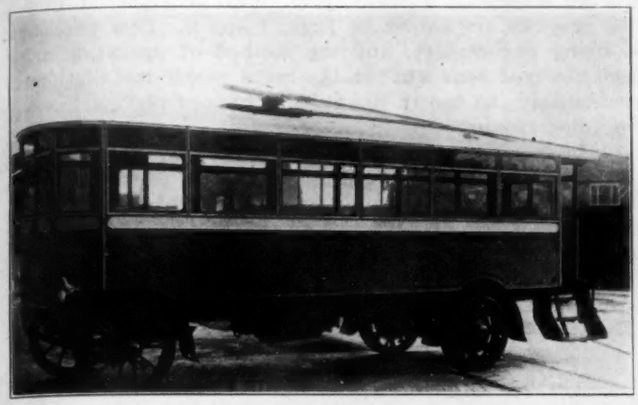

FIG. 1—A TYPE OF TROLLEY BUS THAT HAS BEEN DEVELOPED FOR USE IN ENGLAND

railway organizations. By such means, existing properties representing a large investment can be preserved and applied to a much greater range of service activity than was ever contemplated by the founders of these public-transportation organizations.

A general specification of the desired requirements of street-railway organizations in providing transportation service through flexible vehicle-equipment will be found in the report on this subject of a committee of the New England Street Railway Club dated Feb. 2, 1922, extracts from which are given in Appendix 1.

THE TROLLEY BUS AS ONE SOLUTION

Obviously, the first step in this general direction would be a broader application of the trolley bus as constituting a means for the solution of some of the existing railway-organization problems. It cannot be expected to solve all these problems, but it must be admitted that the desirability of its use in many cases is indicated clearly.

The use of the trolley buses in European countries has been covered in a very comprehensive way by H. L. Andrews, of the railway and traction-engineering department, General Electric Co., who, in an article entitled The Possibilities of the Trackless Trolley,[3] points out that

> European countries have for a great many years successfully operated trackless trolleys. In 1920 there were in England 20 companies with more than 100 miles of trackless-trolley installations operating or authorized, while Italy had 8 companies comprising a total of 43.5 miles of route, and Germany had 8 installations for passenger and freight traffic. France, Sweden and Austria have a number of installations in successful operation.

The three general systems in use in Europe are the Mercedes Stoll, the Filovia and the Max Schiemann, all of which differ in the method of drive and in the method of collecting current.

The Mercedes-Stoll system is essentially a four-wheel drive, although two-wheel-drive installations have been made. The driving motor is built into and is a part of the driving wheel. The control is arranged to give six speeds and three electric-brake positions. When used with the two-wheel drive, the motors are connected in series for the first three points and in parallel for the last three positions. The arrangement for the four-wheel drive differs from the two-wheel drive only in having the two front-wheel or the two rear-wheel motors connected in series.

The collector used with the Mercedes-Stoll system is of the overrunning or carriage type. The current collector at the trolley end is composed of a frame having two small grooved wheels with ball bearings on each side, one pair running on each wire. A cable with a double wire hangs down from the center of this frame or trolley and has a weighted pendulum that keeps the wheels well pressed down on the wires. This collector allows considerable movement from the trolley wire, and extreme movement is taken care of by a cable and a reel on the car that allows a 30 to 35-ft. radius from the center of the trolley. When vehicles operating in opposite directions meet, the drivers exchange collectors and plugs, which are detachable readily and within easy reach.

This system for the collection of current has proved successful, but has the disadvantage of requiring special overhead-construction and, in case the carriage leaves the trolley wire and falls to the street, it is damaged considerably. The arrangement of mounting the motors directly on the driving axle requires low-speed motors with a low efficiency and a great weight. The maintenance on the motors is higher than if they were spring supported, due to the fact that they receive all of the hammer blows from the road. For the most part these trackless trolleys weigh approximately 6048 lb., less the load, and have a seating capacity of 25 persons. In some few installations larger cars weighing over 11,000 lb., complete, are used. One installation is equipped to handle motor and trailer cars; the motor cars having a seating capacity of 22 and the trailer cars of 20 people.

The Filovia system, which is in operation on more than 40 miles of route with eight different companies, has proved very successful. This system adheres to a two-motor drive, each motor being mounted on the chassis and geared to a jack shaft on which is mounted a sprocket wheel. Transmission of power to the rear wheels is by a chain drive. Each car is equipped with two 12-hp. motors. The collectors used are similar to those described with the Mercedes-Stoll system, except that they are connected to the bus by a rigid pole.

The Max Schiemann system has been employed extensively in Germany for both passenger and freight service. There are eight or more installations, three of which are strictly passenger service, four are entirely for freight and one handles both freight and passengers. This system uses a two-motor drive, each motor being

FIG. 2—ANOTHER EXAMPLE OF ENGLISH EQUIPMENT
Two Motors, Each Driving the Two Wheels Independently, Are Used. The Tractor Arrangement Provides a Floor for the Car That Is 14 In. from the Ground. All of the Load Is Carried by the Rear Axle Since It Is Located Midway under the Load-Carrying Portion of the Vehicle

[3] See *Electric Railway Journal*, Dec. 4, 1920, p. 1136.

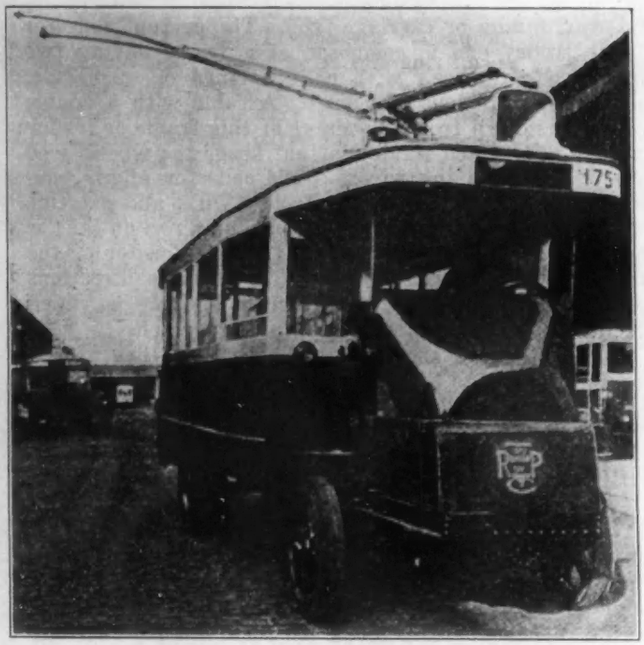

FIG. 3—THE TYPE OF TROLLEY BUS THAT IS USED IN PARIS

mounted on the truck chassis and geared to a jack shaft by bevel gears. Power is transmitted to the rear wheels by a chain drive. The three methods of collecting current used with this system are (*a*) two trolley poles under-running on the trolley wire; (*b*) one trolley pole with a double head carrying two trolley wheels; and (*c*) an over-running carriage as described under the Mercedes-Stoll system. This last method of collecting current has not produced good results, due to the damage resulting from the carriage leaving the trolley wire.

NATIONAL PRACTICES

English practice differs somewhat from any of the three systems previously described. Two motors are used, each being mounted on the truck chassis and connected to a jack shaft through worm gearing. The jack shaft carries a sprocket wheel, and power is transmitted to the driving wheels by a chain drive. Two examples of English practice are shown in Figs. 1 and 2. This practice of using two motors, and the method of operation has been changed somewhat in the more recent installations, particularly the one in Shanghai, China. On these buses, two motors that are mounted directly on the chassis are used; but the jack shaft and the chain gearing are omitted, the motors being direct-connected to the driving axle through worm gearing, and each motor drives one of the rear wheels. English operators who have used the gasoline-propelled bus more extensively than we have until recently in this Country, both independently of their railway systems and as feeders to their established lines, have stated that the gasoline-propelled bus, so far as it has been developed, cannot be operated at the same cost as the street car and that they are not well adapted for handling peak loads. But they have found the gasoline bus well suited to operate as feeders or to connect-up existing street-railway routes.

The Paris transportation-system is now operating trolley buses of the type shown in Fig. 3 as extensions of the trolley lines in rapidly growing suburban sections.

In the United States and in Canada, recent installations have been made on Staten Island (See Fig. 4) and in New York City; Baltimore (See Fig. 5); Richmond, Va.; Minneapolis (See Fig. 6); Los Angeles; Toronto (See Fig. 7), and Windsor, Ont., Canada. (See Fig. 8).

[4] See *General Electric Review*, December, 1921, p. 974.

[5] See *Electric Railway Journal*, Feb. 28, 1920, p. 424; April 3, 1920, p. 683; April 24, 1920, p. 849; May 29, 1920, p. 1088; July 3, 1920, p. 11; and July 31, 1920, p. 209.

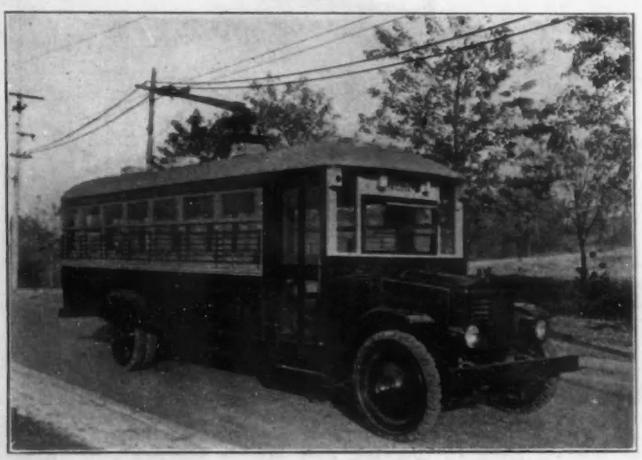

FIG. 4—THE TROLLEY BUS THAT HAS BEEN RECENTLY PLACED IN SERVICE ON STATEN ISLAND, NEW YORK CITY

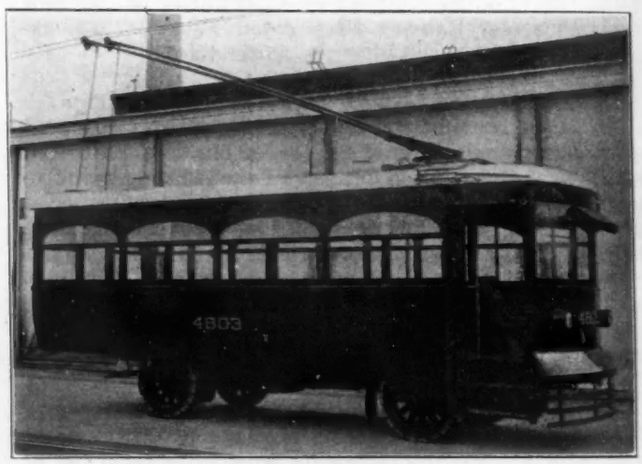

FIG. 5—A REPRESENTATIVE OF A NEW INSTALLATION OF TROLLEY BUSES AT BALTIMORE

In an article entitled The Prospective Fields For the Rail Car, Trolley Bus and Gasoline Bus in City Transportation,[4] this subject has been treated in great detail by J. C. Thirlwall of the railway and traction-engineering division of the General Electric Co. Extracts from this article are given in Appendix 2.

The six-part article entitled The Place of the Motor-bus in Passenger Transportation,[5] by Walter Jackson, is well worthy of the attention of automotive engineers. Some extracts from it are given in Appendix 3.

In this trolley-bus form of machine the vehicle is released immediately from the handicap of running on tracks, and while it is, so to speak, tied to the trolley wire, the flexibility of movement has many real advantages. It is free to pass roadway obstacles and can pick up and discharge its passengers at the sidewalk. Incidentally, its operation may relieve the railway organization from street-paving obligations, and there should be a decided further economic advantage in a lower cost of mechanical upkeep because the vehicle operates on rubber tires.

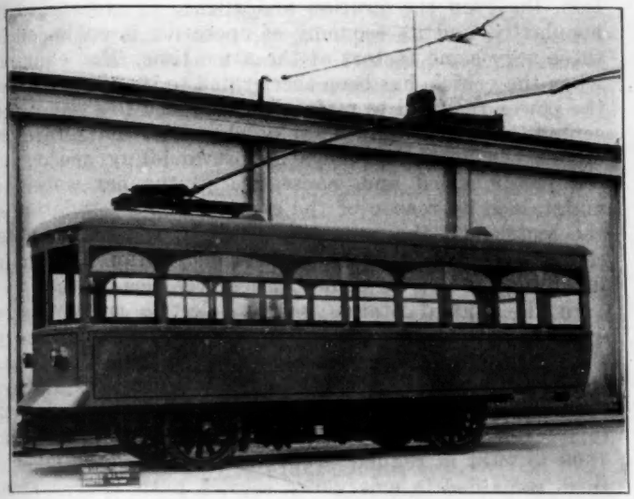

FIG. 6—VEHICLES OF THE REGULAR STREET-CAR TYPE HAVING A SINGLE POLE WITH A FORK FOR MAKING CONNECTION WITH THE TROLLEY WIRE ARE IN SERVICE AT MINNEAPOLIS

Its employment requires practically no changes in the organization for operation and maintenance and, with the use of central-station energy, it should be able to compete with buses operated by gasoline costing a much higher and varying price for the power required in transportation, as well as a lower upkeep cost by the use of electrical equipment for frequent speed-changes as compared with mechanical transmissions. Another important consideration in this direction is the possibility that, within a short time, taxation of the use of gasoline on a gallonage basis which exists at present in a number of States may become a general practice throughout the Country, which would prove a serious handicap to a public-service organization continuously operating large numbers of machines.

DUAL-POWER BUS-EQUIPMENT

The next logical step in the development of more flexible vehicle equipment would be the inclusion in the trolley bus of a secondary source of power for supplemental operation. This may be either a gas-engine equipment or an electrical auxiliary in the form of a storage-battery chargeable either from the line or at the power station. The obvious advantage of either of these is that supplemental vehicle-service could be rendered beyond the limitations of the trolley, and in this way there would be a marked increased earning capacity in a machine so equipped. From an investment standpoint, in going into new territories, such a dual power-equipment would require only a partial installation of overhead line-construction, permitting the vehicle to be operated beyond these extensions in various directions until the earnings from such extended service would warrant the additional investment in further line installation. Another place for the use of such a vehicle would be in those instances where short non-paying trolley-lines already have been abandoned and which have paying territories adjacent to them either laterally or beyond their zones. In other words, the resuscitation of such lines by this means would provide for return parallel routes in better paying localities or an extension of the service beyond the point where the existing lines end. Therefore, whether the auxiliary source of power should consist of gasoline or electrical equipment would depend upon the extent of off-line service to be rendered, particularly considered over long-time periods or years of operation. For instance, if operation from the trolley line was 75 per cent of the bus route and the auxiliary service 25 per cent of the route, gasoline equipment would be indicated. If the off-line service represented 50 per cent of the performance it would become desirable to use central-station power and, for this purpose, an electrical equipment would be indicated. It is well to accentuate here that such electrical equipment in the form of storage-batteries, if charged intermittently from the line, would not require to be very large, because the intermittent off-line service is not likely to be at any time more than a mile or two of operation and a comparatively small battery would serve this purpose. The employment of such a battery equipment with a means for intermittent line-charging would have to be weighed from an economic standpoint with the contrasting factors of the use of cheap central-station power against the use of gasoline.

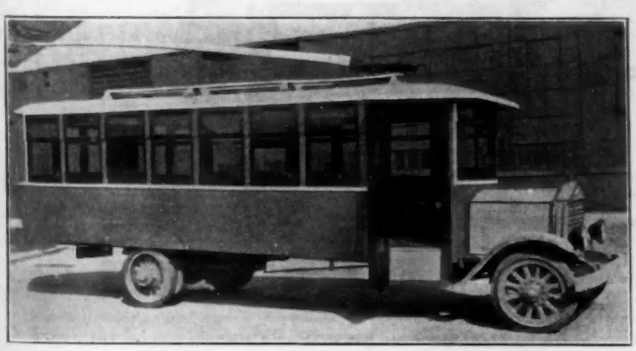

FIG. 7—TYPE OF TROLLEY BUS THAT IS IN OPERATION AT TORONTO This Vehicle Follows the Conventional Bus Construction and Has the Control Mechanism under the Hood

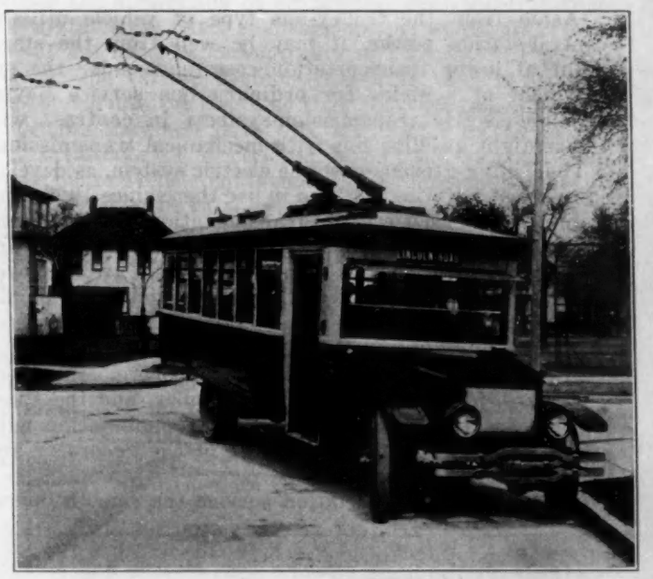

FIG. 8—TROLLEY BUS IN SERVICE AT WINDSOR, CANADA

In applying such trolley or dual-power buses to existing lines where trackage and a single overhead trolley is or has been in use, avoidance of installing the second overhead wire might be effected by the use of rail-contact devices incorporated in the vehicle. The advantages and disadvantages of such compromise equipment would have to be weighed in each case, but trolley-bus operation with a rail-contact device is well within the range of feasibility. A still further factor in the general situation is that the more broad the use of such trolley buses be-

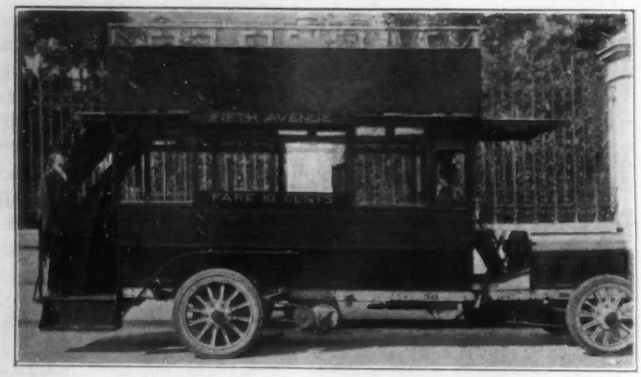

FIG. 9—ONE OF THE GASOLINE-ELECTRIC BUSES THAT OPERATED ON FIFTH AVENUE, NEW YORK CITY, FROM 1905 TO 1917
This Bus Was Equipped with Two Motors That Drove the Rear Wheels through Chains

comes, the cheaper the vehicles would be. Naturally, with a limited output of these, the price at the moment is higher than it would be when numbers of them were constructed.

INDEPENDENT BUSES WITH ELECTRIC TRANSMISSION

Aside from the trolley-bus type of vehicle utilizing central-station power, it may be well from the standpoint of lower transportation cost to consider the employment of vehicles for ordinary bus service having gasoline-electric transmission-systems in contrast with the straight gasoline bus with mechanical transmissions.

The Tilling-Stevens gasoline electric system, as developed in Great Britain, has been in use there since 1908; and, at present, at least a dozen transportation companies employ fleets of from 20 to 300 motorbuses of this type, and very many more vehicles using this system are employed as motor trucks. This system is particularly simple, consisting of a gasoline engine having directly connected to it an electric generator. A separate electric motor is used to drive the propeller-shaft. The control consists of a forward, neutral and reverse controller, and the speed is regulated by the engine throttle in combination with a lever varying the field resistance of the generator and the motor.

In passenger-transportation service the smooth operation, the even acceleration and silence contribute to its popularity, and its economy of operation is enhanced by these very same factors at the same time. For example, when the vehicle has been accelerated to its normal speed, the power required to maintain this speed is a small percentage of that required for acceleration. Therefore the engine can be slowed down almost to idling speed; but the motor speed and, consequently, the car speed, is maintained by reason of the change in the regulation of the motor and the generator fields. Well substantiated claims are made that both fuel-consumption and maintenance costs are very low in these vehicles.

In the United States, gasoline-electric transmission-systems have been used in various forms from time to time for many different purposes in the freight and passenger-transportation fields and for military-equipment requirements. In motorbus service, the Fifth Avenue Coach Co. used a group of 10 buses (See Fig. 9) from 1908 to 1914 in regular schedule operation, and some of them remained in emergency service until 1917. These were designed by H. S. Baldwin, an automotive engineer, and built under his supervision by the General Electric Co. The electric-transmission system employed in these vehicles was entirely satisfactory from an operation standpoint, although they were somewhat handicapped by being used with gas engines that were not entirely suitable. This type of transmission equipment would have been continued except for the fact that it was not in regular production and, therefore, could not compete with the mechanical-transmission equipment that was more readily available in the market.

Prior to the use of this group of machines, an experimental vehicle designed by Mr. Baldwin was put into operation in 1905. This is interesting from the fact that the engine was started electrically, using the generator as a motor, and was, therefore, probably the first vehicle to embody this self-starting feature. Incidentally, it had a semaphore signal at the back which was thrown into a horizontal position by the torque of the motor when the vehicle started, and which was returned to a vertical position by a recoil spring when the vehicle stopped. A high-speed electrically operated fan was used also to cool the radiator coils, which provided high ventilation with the vehicle running at low speeds. The equipment of these buses is described in articles by H. S. Baldwin

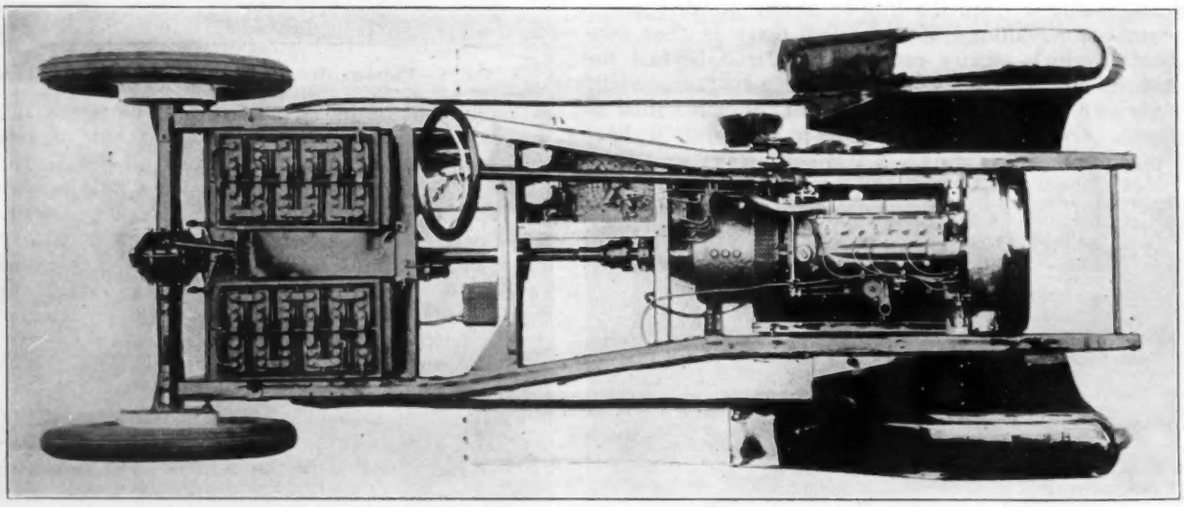

FIG. 10—A PRACTICAL AND SIMPLE GASOLINE-ELECTRIC SYSTEM THAT HAS BEEN IN SERVICE AT CHICAGO SINCE 1917
The Vehicle Is Started by a Small 24-Cell Storage-Battery That Supplies Current to a 12-Hp. Motor. The Gasoline Engine Takes Care of the Continuous Running of the Vehicle. Since the Engine Is Larger Than Is Required to Propel the Vehicle After Acceleration, the Excess Power Is Used to Operate the Motor as a Generator and Charge the Storage-Battery

entitled Gaso-Electric Motorbuses on Fifth Avenue, New York City[6]; and Some Special Applications of Gasoline-Electric and Storage-Battery Automobile-Equipments.[7] A later example of a gasoline-electric system is illustrated in Fig. 10.

Bus service is distinctly different from any other of the several forms of motor-vehicle operation with which we are familiar, inasmuch as the machine is repeatedly operating over a fixed route where the road-surface conditions are constant except for varying weather conditions and periodic seasonal changes. The other operating conditions, such as the mileage, the speed and the number of stops per mile, as well as the average load carried, are almost equally fixed and constant; so, with all these operating factors known in advance, it is comparatively easy to determine the relative advantages of one particular equipment as against another.

In bus operation, the cost of constantly recurring speed changes is an important factor, not only with reference to the upkeep of the transmission, but also the dynamic influence of these stops and starts upon the wear and tear of the other parts of the vehicle such as tires, brakes and the like, with particular emphasis on the fuel consumption; and it is in reference to these considerations that the use of electric transmissions may be of very much greater importance in this field of service than they have been hitherto in the use of motor-vehicle equipment. Electric-transmission systems have been in use successfully for long periods in bus operation; whereas, for regular merchandise haulage, there has not been equal progress with such equipment. The reason for this lack of progress will be obvious to anyone studying the situation, which is governed largely by the influence of competing apparatus made in quantity and much more familiar to the average user.

Just prior to the war, a committee of the Metropolitan Section of the Society, including myself, made an extensive research into what had been done in this field throughout the world. A report is on record that indicates the findings of this committee in brief, as the subject was so broad as to render a more complete report impracticable at that time. It is well known that many systems of electric transmission have been devised and applied, but their use has not become general for the reason that quantity production was never attained in any case. Consequently, it was difficult to compete with products being made and used on a mass-production basis combined with a natural tendency on the part of the common user to employ what exists in ordinary practice instead of utilizing new departures, notwithstanding whatever the economic advantages might be.

With the coming of a very general application of automotive equipment to public passenger-transportation, particularly in the hands of existing railway organizations, the reason for the existence and the employment of electric-transmission equipments is changed materially, and the serviceability of these, based upon their value in reducing the cost of operation and upkeep, is likely to bring these systems into active use. As a matter of fact, all of the parts required for such equipment exist as standard units having other applications, and the almost universal employment of electric starting-sytems in automobile equipment has dissipated much of the mystery and the ignorance that previously prevailed and constituted a serious handicap to the use of electrical

[6] See *General Electric Review*, November, 1908, p. 214; see also *Street Railway Journal*, Dec. 2, 1905, p. 986.

[7] See *General Electric Review*, March, 1912, p. 127.

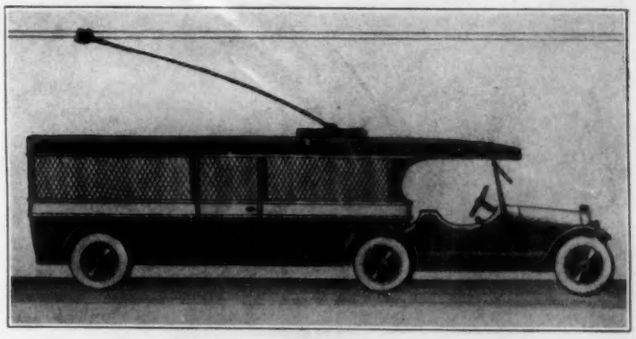

FIG. 11—A TYPE OF VEHICLE WITH A TROLLEY POLE ON THE TRAILER THAT IS SUITABLE FOR THE TRANSPORTATION OF PARCEL POST OR EXPRESS MATTER

equipment for any purpose where its use could be avoided.

The electric street-railway organizations, being in effect electric-transportation engineering-institutions, should be more inclined to prefer electrical equipment than mechanical; and it is logical, consequently, to forecast that the obstacles which have existed heretofore to impede the application of economical electrical-transmission systems are likely to disappear. It would, therefore, be well for automotive engineers to refresh their knowledge of the various systems that have been in isolated use for various purposes, so that any superior operating value that they may have will be available to the operating advantage of electric street-railway organizations using motor-vehicle equipment. One important phase of the case should be emphasized in the following consideration, that in electric-transportation organizations competent care and maintenance for the particular features of these equipments is available more readily than anywhere else. Another is that all of the electrical equipment necessary is available from the same large manufacturing organizations that have been the sources upon which railways have depended for their equipment requirements in the past. As in the case of the trolley bus, this specific type of machine is not recommended as a "cure-all" to meet every requirement, but its importance is now accentuated more than ever before.

BODY AND CHASSIS REQUIREMENTS

Body and chassis requirements peculiar to mass transportation constitute a subject that, from the standpoint of the designer and the manufacturer, has not yet received much consideration; at least, it has been sidetracked by the necessity of making use of material and equipment designed for other purposes, but constituting the only kind immediately available for application to

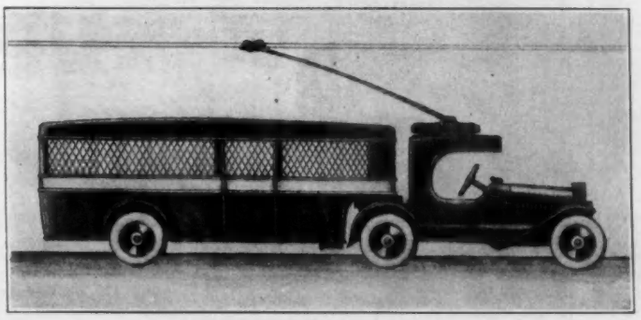

FIG. 12—ANOTHER POSSIBLE TRACTOR AND TRAILER ARRANGEMENT WITH THE TROLLEY POLE ON THE TRACTOR

FIG. 14—A SUGGESTED VEHICLE FOR LONG-DISTANCE WORK

motorbus construction. Manufacturers dependent upon other lines of business as their main source of revenue are not deflected easily into a new channel where the prospect is indefinite, the demand intermittent and the varying operating requirements necessitate many changes from their standardized products. Naturally, therefore, what they have produced has been furnished with hesitancy and loaded down with handicaps. Some few manufacturers have made changes in their equipment as far as might reasonably be expected, with the purpose of encouraging development in this "new-business" line; but, on the other hand, many manufacturers have refused to depart from their standard products, leaving the responsibility of any misapplication made resting upon their agents. The agent, on the other hand, being forced to maintain his existence under the trying business conditions that have prevailed in recent years, particularly in the motor-truck field, has, in many cases, been desperate to make use of any business opportunity presented, and, "none being so liberal as the desperate," they have conspired with the local blacksmith and the local wagonmaker, not forgetting the finishing touches of the painter and the decorator, in attempts to produce compromise vehicles built upon truck chassis. In most instances these makeshifts have been heinous violations of the designer's art, as we know it from an engineering standpoint and, in a few years from now when a rational advance has been made in proper design, these machines will be held up to us as horrible examples of our earlier ignorance and incompetence.

Is it any wonder, then, that we find the conservatively trained executives in public passenger-transportation fields in such an attitude of reluctance to adopt this misfit equipment that violates, from every point of consideration, the tradition of their industry as developed by years of experience? We should acknowledge immediately the radical difference existing between their experience and ours as automotive engineers. We are principally concerned with the design, the construction and the application of isolated unit vehicles where, in the passenger-car direction, speed, luxury and comfort are an ultimate attainment; and, in the commercial direction, the standardized production of merchandise vehicles that would operate with tolerable satisfaction under a great variety of service conditions. The street-railway engineer and the executive, on the other hand, have been required to provide the continuous performance of a rigidly standardized transportation under conditions where failure and interruption are not tolerated, where the good will of large communities of patrons must be catered to and often complied with under trying conditions, and where "safety first" has even been more vital than continuity of operation.

FIG. 15—HOW A SEMI-TRAILER AND TWO TRAILERS MIGHT BE HAULED BY A TRACTOR

The Tractor Might Be Used Away from the Line to Collect the Trailers and Would Then Come Over to the Line as Shown to Be Operated with Central-Station Power for the Large Portion of the Run

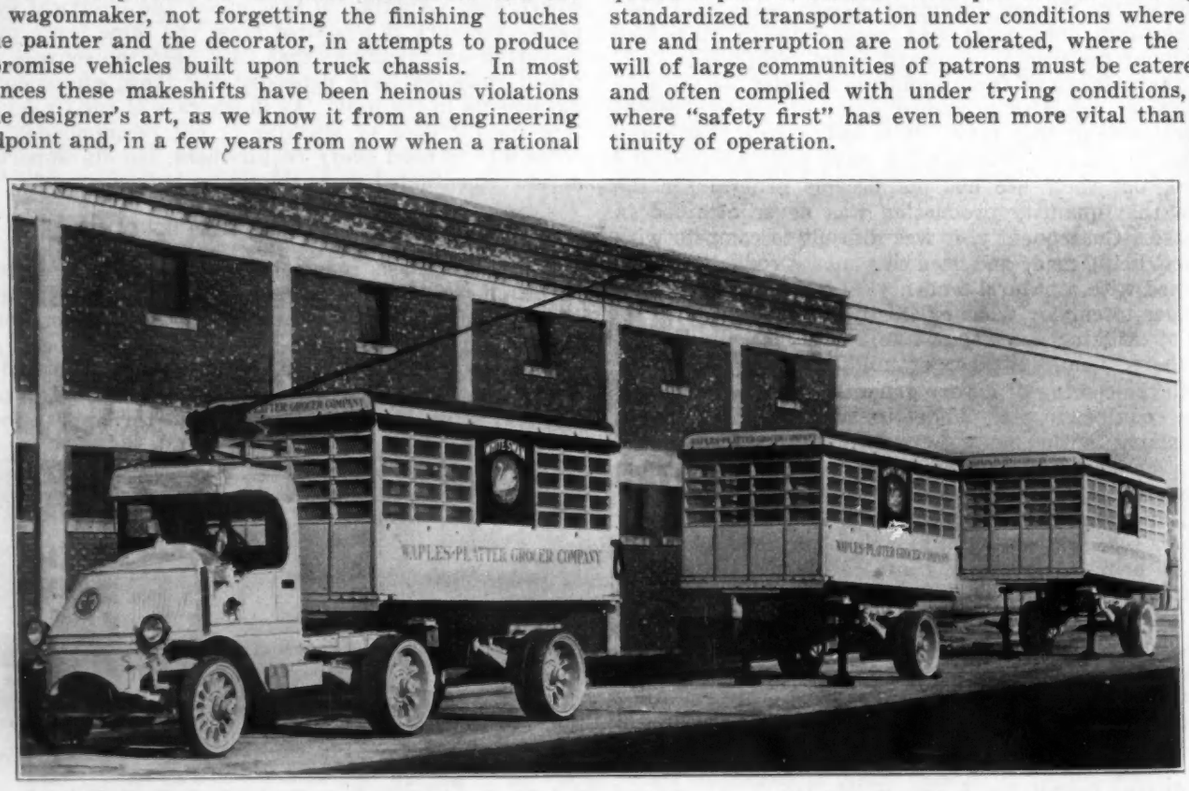

FIG. 13—STILL ANOTHER ARRANGEMENT IN WHICH THE STREET-RAILWAY COMPANY WOULD SUPPLY THE TRACTOR AND THE MERCHANT WOULD EITHER OWN OR RENT THE TRAILER

Public-Service-Transportation Permanency

Solidity and permanency of organization have been absolutely necessary, and many obligations of a municipal, political and regulatory nature, have had to be complied with as requirements to legal or actual existence. Therefore, we should feel pretty sure that any general assumption that the apparent temporary success of independent operators forebodes displacement of the more permanent railway-organization service is entirely delusive and that, within the lapse of a short period, these organizations will seriously determine upon a rational program for graduated advance in directions of the newly demanded service.

The problem of developing satisfactory equipment is not solved readily; it demands a serious study on the part of both the railway and the automotive engineer. The nature of the undertaking should impress us with its importance, and definite steps are warranted in recognition of the enormous progressive possibilities opened up to both the automotive and the railway industries in meeting new expansion in directions that have not been contemplated previously by either of these industries.

Prospective Street-Railway Business

It requires no stretch of the imagination to realize what may be accomplished if these well founded and experienced transportation organizations, by the collaborating influence of the automobile industry and the consequent employment of flexible vehicles, should be suddenly released from the rail and wire restrictions that have limited their operations definitely to almost a single field of service. With flexible vehicles operated to a large extent under the advantages of central-station power and distribution, new fields of business development are opened immediately. Their city passenger-transportation can be augmented materially with very much less investment requirement than similar expansions called for previously. Sightseeing transportation is legitimately within their business province and summer touring-service is a prospective possibility; but, more important than these, is the opportunity to handle the local transportation of merchandise, parcel post and express, as well as local freight-transfer for merchants and manufacturers, and the possibility of collaborating with the steam railroads in putting into execution the recently much talked of store-door delivery. Such operations may require changes in the limitations of their existing franchises, but these changes or enlargements should be secured readily in view of the advantages rendered to their communities by the increased transportation facilities afforded. Their ability to supply a highly organized, economic and varied line of service to the business interests in their immediate vicinities should certainly fortify them in demanding the rights necessary to conduct these progressive and improved operations. Examples of equipment that might be used for such transportation are shown in Figs. 11 to 15.

Heretofore, the transportation of freight by street-railway equipment has not been very general in this Country; nevertheless, the possibilities for business in this direction are so extensive as to warrant the energetic action required to bring it into common practice. Necessity, "the mother of invention," in developing the ways and means to accomplish this may have been lacking in the past; but, in the light of necessities that have existed in Europe, we have some good examples of what can be done under pressure. In Appendix 4 is an extract

[8] See *Electric Railway Journal*, May 22, 1920, p. 1062.

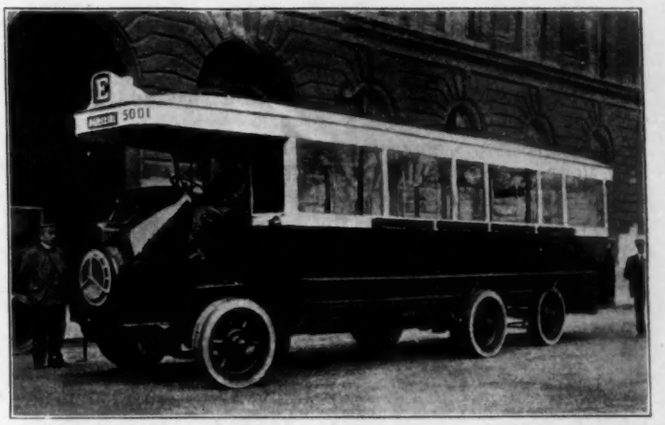

Fig. 16—A French Six-Wheel Gasoline Bus in Which Both the Front and the Rear Wheels Perform Steering Functions

from an article entitled Teuton Trolleys Handle Freight[8]. Briefly this shows that in Germany, as long ago as 1903, there were 60 of the 148 street railways then in use that were handling freight. In 1913, there were 60 of the Prussian street railways and 19 of the railways in other German states that were handling freight, with 2600 cars for package mail and freight, of which 964 were regular freight cars of 6-metric-ton (6.61 net tons) capacity each. In Vienna, Austria, up to 1918, local street-railways had made 110,000 car-trips, the equivalent of 310,000 wagon-trips. For the same amount of work, 350 horse trucks or 100 motor trucks would have been needed.

Therefore, the attitude of our street railway organizations, instead of being that of resistance and reluctance toward the use of automotive equipment, should be a complete and energetic change to a realization of the enormous new business fields open to them to invigorate their organizations and to reestablish a happier financial condition by seizing upon this basis of a new start with added fields for progressive development.

Flexible-Equipment Requirements

Having indicated the several directions of possible expansion, we can return again to the body and the chassis equipment necessary to meet these several new requirements. In seeking a solution of this new-equipment problem, we must presuppose a favorable attitude toward new methods to be adopted, necessarily requiring

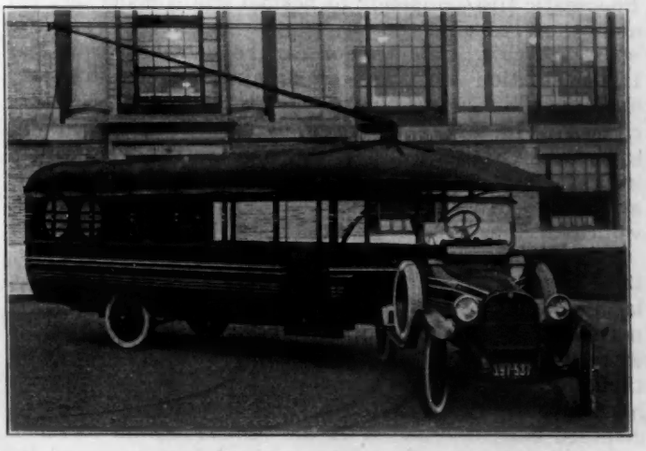

Fig. 17—A Car with a Semi-Trailer That Seats 29 Passengers and Gives a Low, Wide Comfortable Passenger Car Making a Turn in a Comparatively Small Space

trial periods to insure actually the performance required, and to safeguard the investments to be made for such new equipment. Demand principally exists for large carrying capacity with low operation cost and one-man control.

Other features sought are a low center of gravity, a low floor, large seats, wide aisles, compensating spring-suspension and accessibility for maintenance and repair. In operation, there is need for smooth acceleration, ample power, adequate brakes and permanency of the power-plant under continuous operation. Desirable additions in equipment features are a detachability of powerplant and seasonal body changes. Fundamental necessities are interchangeability of parts and standardization of the units employed. These requirements cannot be supplied readily in machines designed primarily as trucks. Their special service requirements demand correspondingly special designs.

Motor omnibuses in European cities are good examples of specialized development. These are not, however, generally recognized as offering a broad solution for American transportation requirements. They are particularly applicable in congested metropolitan zones but, under average American city conditions, something less cumbersome is desirable. To provide for large passenger capacity, longer vehicles of the single-deck type, similar to that shown in Fig. 16, are in demand. This calls for increased distribution of axle carrying-capacity. Some special developments have been provided having double rear axles; some others have provided two rear and two front axles.

A combination tractor-and-trailer design, such as that illustrated in Fig. 17, is not entirely new in passenger transportation, and it certainly has many advantages worth considering. This type of design will provide the following features:

(1) Three axles for load distribution of the passengers and the powerplant
(2) Three sets of springs for flexible suspension
(3) Steering on all six wheels, resulting in a short turning radius
(4) Brake-equipment application to two axles as well as to the drive-shaft
(5) Powerplant equipment confined to the tractor part, and consequent freedom from power-equipment apparatus in the trailer passenger-section

These features allow a wide, low-hung body, comfortably accommodating both seated and standing passengers. Pneumatic tire equipment of normal size is made serviceable, thus reducing the unsprung wheel weights and the operation cost. The tractor can be detached from the trailer section for ease of repair and maintenance. Trailer bodies of open and closed types can be interchanged. In case of accidental damage, only part of the equipment is put out of service; and a carrying capacity up to 100 passengers can be provided for within reasonable length of vehicles. Illustrations of various types of vehicle are shown in Figs. 18 and 19.

With such a brief summary of this particular design, it will be seen readily that, in meeting the demands for larger passenger capacity than is supplied usually by the normal four-wheel vehicle, there is an opportunity to extend the load space and distribute its weight on a rational basis. Extending the length of vehicles usually handicaps their turning ability; but, with three axles disposed along the length of the vehicle and all of them performing turning functions, controlled or governed in a specific manner, any reasonable turning radius required for city operation can be attained. The consequence of all these features is that an approach is made to meet the demand that the street-railway executive asserts exists in the necessity for handling a large number of people comfortably and flexibly with one-man control.

This type of vehicle, having included in its power operating-equipment the combinations necessary to utilize central-station power or to operate independently, is a step in the direction of the least departure from the existing practice in street-railway organizations. It provides for the utilization of the cheap power that they are equipped to furnish and tends fundamentally toward the preservation of their existing property and investment with a marked extension in the radius of application of the transportation service in new and profitable directions.

A somewhat similar application of tractor-and-trailer equipment for freight haulage and package transfer would similarly extend the earning power of these corporations to a marked degree. It is easy to realize that, with the cooperative agreements necessary, a tractor of the railway company having dual power-equipment could transport the loaded trailers of merchants and manufacturers between various points within the operating zone with the utilization of central-station energy for a large part of the performance. Where permanent cooperating relationships could be established by the street railways and the steam railroads for the conduct of store-door delivery between the railroads and their customers, flexible operating equipment and adequate line facilities would be justified. Even if the latter involved a considerable investment in permanent overhead structures within the zones of greatest traffic, such transportation would bring to the railway organizations substantial and permanent revenue for operations well within their scope and entirely justified by reciprocal economic advantages. Fig. 20 gives an example of the extent to which the tractor and the trailer are coming into use by large transportation companies.

With problems such as these existing in directions that have not heretofore existed for either the street-railway or the automotive industry, and including both business and engineering opportunities, there should arise immediately a progressive energetic response in joint cooperation to meet the purposes of both parties. The field for expansive activity is enormous and the automotive industry should immediately recognize that in the street-railway organizations, taken collectively, there exists a greater potential group-consumer for its products than has ever existed in any single direction. In other words, here we find what can be regarded practically as a unit group of customers experienced as no others have been in the utilization of transportation equipment, with requirements that are uniform in character and with executives and engineers particularly qualified to coordinate with the engineers and executives of the automotive industry.

APPENDIX 1

In a report to the New England Street Railway Club Committee made Feb. 2, 1922, the committee calls attention in a general way to features that should be taken care of in the construction of a bus, without discussing the proper type of gasoline engine for the bus. Briefly, these are

(1) Reliability and ability to render uninterrupted service 18 hr. daily
(2) A high degree of riding comfort, not obtainable

by a common motor-truck chassis with a body hung on it. There should be (*a*) proper spring suspensions, (*b*) as little rear-end overhang as possible and (*c*) a low center of gravity. The bus must be more comfortable to ride in than a street car, if possible

(3) That tire and wheel equipment be fitted to the roadway

(4) An absolute reliability of brakes

(5) Not more than two 15-in. steps for ingress and egress

(6) An attractive body appearance from the inside and the outside

(7) A rapid pick-up and rapid braking speed

(8) A low gasoline consumption

(9) Good ventilation and light

(10) A seating capacity of 21, 25 or 29 passengers

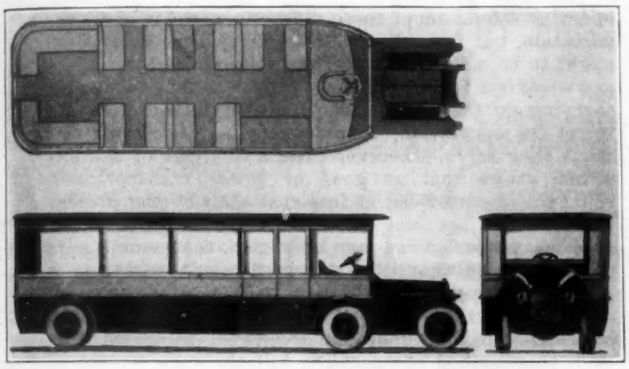

FIG. 18—ANOTHER TRACTOR AND SEMI-TRAILER COMBINATION ACCOMMODATING 30 SEATED AND 20 STANDING PASSENGERS

In This Arrangement the Tractor Has a Short Wheelbase and Is Intended To Have Either a Trolley Pole or a Gasoline Engine and a Transmission, There Being No Power in the Trailer. The Tractor Is Detachable from the Trailer for Ready Servicing or the Substituting of Other Vehicles in Case of Damage to Either Member of the Combination. The Steering Is Performed by All of the Axles and the Steering Functions of the Rear Wheels Are Controlled by the Angular Movement of the Tractor

In its discussion on the trackless trolley, the committee gives the history of its development which, the report says, started in Berlin, Germany, with a line constructed by Siemens & Halske Actien Gesellschaft. Most of the developments have been abroad, in Germany, Italy, France, Great Britain, Shanghai, China, and Rio de Janeiro, the last being a storage-battery line, and there being one line built at Los Angeles, in 1910. Only recently have there been any serious attempts to develop the trolley bus in this Country.

In the whole world, the committee points out that, the development of this vehicle has extended to not more than 200 miles of line operating under widely different conditions. The committee also points out, however, that experience with these few lines should be valuable because, if conditions have changed so as to make this method commercially feasible, the experience with designs and types should enable present-day users to avoid mistakes of the past. The committee then states

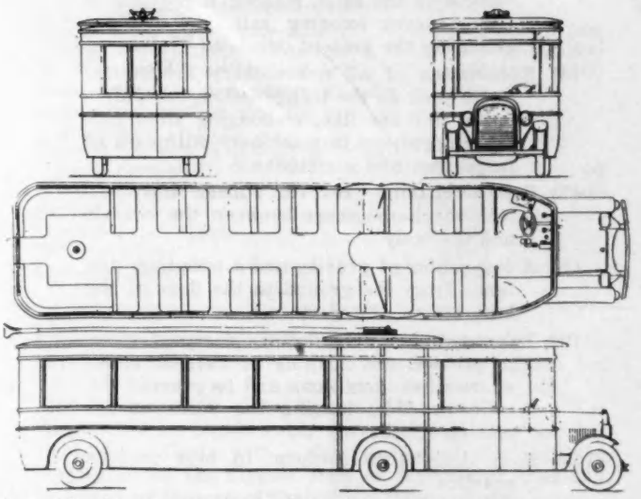

FIG. 19—ANOTHER ILLUSTRATION OF THE POSSIBILITIES OF THE TRACTOR AND TRAILER ARRANGEMENT

This Vehicle Will Seat 50 Passengers and Has Space Enough To Accommodate 40 or 50 More Comfortably. It Is Intended for Operation from the Trolley Line or by a Gasoline Engine and Has Both an Electric Motor and a Gasoline Engine and a Transmission, thus Necessitating a Long Wheelbase for the Tractor. One Man Operates the Vehicle and Has Both a Controller for Electrical Operation and a Gasoline-Engine Control. The Brakes in Both of These Vehicles Are on the Driving Wheels and on the Rear Steering-Wheels. As a Fifth-Wheel Connection Is Provided over the Center Driving Axle, the Steering Functions Are Performed by All of the Axles and It Is Possible To Turn the Vehicle Which Is 36 Ft. Long in a 30-Ft. Radius

Assuming that there is a field for the trackless-trolley bus, it seems to the committee that in developing a suitable vehicle the following desirable features should be incorporated

(1) Two or four-wheel drive and two or four-wheel braking, depending on the weight of the vehicle

(2) Power applied as directly as possible to the wheels

(3) Series-multiple control

(4) Some storage-battery capacity, floating on the line to give greater flexibility in case of blockades and the like

(5) An adjustable device for grounding the

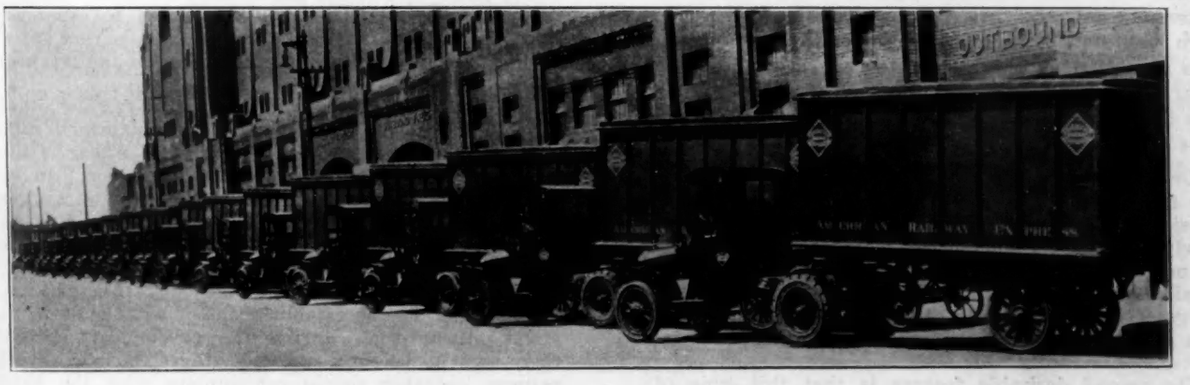

FIG. 20—AN EXAMPLE OF THE EXTENT TO WHICH THE TRACTOR AND THE TRAILER ARE COMING INTO USE FOR PACKAGE AND FREIGHT TRANSPORTATION

vehicle to the rails, making it possible to operate over existing rail lines without changing the present overhead system

(6) Elimination of all unnecessary mechanical parts such as the transmission, the differential and the like, embodying simplicity and ruggedness in machinery with ease of inspection and maintenance

(7) Solid or cushion tires with rubber or equivalent shock-absorbers between the chassis and the body

(8) A low center of gravity and a minimum distance from the ground to the floor of the bus, not to exceed 30 in.

(9) Improved current collectors designed so as to prevent any leaking of current under all weather conditions and to prevent the collector from leaving the wires at operating speeds

(10) Body designs to conform to best modern practice

(11) Minimum weight consistent with these features, with a seating capacity of about 21 to 29 passengers

The committee concludes that there are no really reliable data as to the cost of operation of trolley buses in America now, and therefore gives some of the costs experienced at Leeds and Tees-side in England. Therefrom, it makes some suggestions of its own as to the cost of trolley-bus operation, on the assumptions stated in table 1.

TABLE 1—ASSUMPTIONS OF THE NEW ENGLAND STREET-RAILWAY-CLUB COMMITTEE

Schedule Speed, m.p.h.	10
Time Buses Operate, per day, hr.	18
Bus Capacity	25
Buses Necessary to Buses in Operation	2
Cost of Trolley Line per mile	$6,000
Cost of Each Bus	$7,500
Life of Bus, years	10
Cost of Power, cents per kw-hr.	2
Power Consumption per Bus-Mile, kw-hr.	1.5
Cost, per Set of Solid-Rubber Tires	$200
Life of a Set of Solid-Rubber Tires, miles	10,000
Overhead-Line Maintenance and Depreciation, per cent	10
Equipment Maintenance, per Bus-Mile, Assumed the Same as Car Equipment, cents	5
Hourly Wages of Operators, cents	63

When this is computed for a year at a total mileage of 65,700 miles and a total cost of $16,800.45, the total operating cost per bus mile is 25.51 cents. This, of course, does not allow for dead mileage or for the use or the maintenance of the highways. The last item, even though covered by the community through taxation, should nevertheless be added to the operating cost in any comparison.

The committee lists the following desirable and undesirable features of the trolley bus

Desirable Features.—The chief desirable feature of the trackless trolley is that it makes possible the extension of lines to furnish transportation facilities to newly developed communities, where the traffic must of necessity be light for a considerable period, at a small capital expenditure. This admits of the possibility of changing to car operation later without the loss of any appreciable amount of the capital thus invested.

The second desirable feature is that this type of vehicle lends itself very readily to operation by street-railway companies because its general characteristics are the same as those of the trolley car, making it possible to operate it with the same transportation and maintenance organization as that of the usual street car. Another desirable feature is its flexibility, which, of course, is greater than that of any type of electric car, and the last is curb loading and unloading.

Undesirable Features.—These include lower operating speeds, lower carrying capacity than that of a street car, possible difficulties with the current collector and overhead construction and operation upon the highway, the maintenance of which is not under the control of the transportation company.

In conclusion, the committee recommends that New England street-railway men keep constantly in mind the possibility of adopting any one of these methods of operation in the development of their service. It then says

The committee hesitates to recommend in a report of this sort just where any individual street-railway operator should adopt these different methods of transportation, but feels that street-railway men as a whole ought to be quick to recognize the possibilities of these new methods and are in duty bound to adopt them in carrying on the natural monopoly that they have for street transportation of passengers in the various districts they serve, wherever careful analysis of the situation shows that as good or better transportation could thus be provided at less cost than by the present methods.

In the matter of one-man operation, the committee is of the opinion that it has been demonstrated that a properly equipped electric car can be operated by one man under many different operating conditions with advantage to the public and the street railway. Further, this method of operation has the endorsement of our public authorities and should direct our attention to operation of cars with one man wherever careful analysis shows that this can be done to the benefit of the service, all things considered. In addition, the recent development on certain properties of the so-called light-weight double-truck car, whether operated by one man or two, should be studied closely, as the committee believes that there is a considerable field for this type of car, particularly for one-man operation.

Relative to the motorbus and the trackless trolley, considerable advancement has been made during the past year and the builders of each now have in mind to a large extent the needs of the street railways. There are certain portions of street-railway lines now existing where, on account of the expense involved, it undoubtedly is impracticable to rebuild the tracks and where it might be preferable either to abandon or tear up the tracks and, by the addition of another overhead wire, install the trackless trolley. The committee believes that in many instances it would be preferable before even going to the expense of installing the trackless trolley to install a motorbus service over the line on which the tracks have been selected for abandonment, and to try out the motorbus for a period before undertaking the expense of equipment for the trackless trolley.

The committee feels that the street-railway operators should keep these two vehicles constantly in mind when contemplating extensions of lines either within or without the territory now served by them. In the early days of operation on these extensions, we suggest to the operating officials the advisability of using the motorbus until the final route has been established and a sufficient amount of traffic has been created to warrant the expenditure for the equipment of the trackless-trolley line. In the establishment of extensions to the street-railway lines during the development period, there seem to be three different stages that the street-railway operator should contemplate with the three vehicles that have been studied by this committee.

(1) A motorbus service tried out over various routes to establish definitely the route by which it will best serve the public at the least expense

(2) The trackless-trolley service placed in effect after the route has been established and a sufficient number of riders obtained

(3) The laying of tracks and car operation as the community becomes built-up and the receipts warrant the capital expenditure

Once the tracks are laid, the question of one or two-man operation should be carefully figured to determine which will be the more economical and satisfactory, all things considered.

The committee desires to give due credit to the following organizations and publications for information that we have obtained in compiling this report: *Electric Railway Journal;* American Electric Railway Association; *Public Service Aera;* and the annual reports of the Public Service Commission of Massachusetts.

APPENDIX 2

The writer of the article quoted below,[9] J. C. Thirlwall, has tabulated the respective costs on a comparative basis for a variety of conditions. In general, the calculations indicate that

(1) Where rush-hour headways of 3 min. or less are required with safety cars, rail cars are the most economical and, up to 6-min. headways, offer successful competition to the other types where the road is a going concern

(2) On longer headways, the trolley bus appears to have the advantage due to the lower fixed charges

(3) The gasoline bus, on account of higher operating cost, does not offer competition to the rail car until minimum headways of 10 min. are reached on new routes and 20 min. on existing lines

(4) The trolley bus is more economical than the gasoline bus up to headways of 60 min. or longer

(5) The minimum headways in the respective fields are as follows: rail cars, 3 min. or less; rail cars or trolley bus, 3 to 6 min.; trolley bus, 6 to 60 min.; and gasoline bus, 60 min. or more

The tabulations show that the difference in favor of the trolley bus as compared to the rail car operating on headways of 7½ or 10 min. on an existing route is too small to warrant even the suggestion that rails and equipment should be scrapped and replaced with the new form of transportation. It is not until minimum headways of 15 or 20 min. are reached that the estimated saving of the trolley bus over an existing rail route becomes sufficient to justify such a suggestion.

To illustrate these conclusions and to show the premises on which they are based, a number of tables are presented in which a direct comparison is made of the elements of investment cost for a rail system and for the two types of bus. The actual cost of laying rail in paved streets, of erecting overhead-trolley lines, or of building power stations, sub-stations or shops, varies considerably as between different localities, but the unit costs used in the tabulations are believed to represent fair averages for present construction.

For instance, a figure of $60,000 per mile has been taken for single track with few turnouts laid in a paved street; $75,000 for single track with more turnouts for shorter headways; $100,000 as about the lowest estimate for a route-mile of light double-track for safety cars; and $120,000 for a route-mile of heavy track for double-truck cars. In some localities tracks may be laid for less than these figures. In most large cities they would be considerably exceeded; but they are believed to indicate with a fair degree of accuracy the magnitude of the biggest item of investment that can be saved by the use of the rubber-tired vehicle.

[9] See *General Electric Review*, December, 1921, p. 974.

TABLE 2—AVERAGE CONSTRUCTION COSTS

Single Track, per route-mile	$60,000 to $75,000
Double Track, per route-mile	100,000 to 120,000
Trolley Lines, per route-mile	5,000 to 6,500
Transmission Lines, per route-mile	1,800
Generating Station, per Kilowatt of Maximum Output	125
Substation, per Kilowatt of Maximum Output	40 to 50
Shops per Car Used	1,500 to 2,500
Safety Cars	6,300
Double-Truck Cars	12,000
Trolley Buses	8,000
Gasoline Buses	8,000

Overhead-trolley lines using wooden poles with cross spans can be erected for about $5,000 per mile where only one trolley wire and no feeders are required, and for double track with ordinary feeders should not exceed $6,000 per route-mile. The two-wire trolley required for trolley buses costs about $500 per mile more than the ordinary type of construction and $1,000 more per mile when the line is run on both sides of the street. The transmission line is estimated at $3,500 per mile, and it is assumed that the length of the transmission system is one-half that of the distribution lines. A summary of these and other unit-cost figures is shown in Table 2.

The rail car requires an investment in each of the items; the trolley bus dispenses with the track, but necessitates the use of all the other details; the gasoline bus requires an investment in the vehicles themselves, and in storage and shop facilities, but eliminates the remaining construction charges.

On fairly long headways, that is, from 8 to 20 min., the fixed charges on the rail route will exceed the operating costs, and even on a heavy-traffic route, they will amount to 40 per cent of the total cost of operating the line. The handicap of these heavy investment charges has given the gasoline bus its opportunity and enabled the jitneys to compete successfully in many instances with the established traction lines. The gasoline bus has a higher power-bill and a higher maintenance cost than the safety car, and the depreciation of its driving equipment is decidedly more rapid than that of electric motors and control on the rail cars; but, even so, for many conditions of traffic it is the more economical of the two methods of transportation. However, its proponents have frequently tried to force it into classes of service where its higher operating costs

TABLE 3—OPERATING COST IN CENTS PER CAR-MILE

Items	52-Passenger 36,000-Lb. Rail Car	32-Passenger 16,000-Lb. Safety Car	30-Passenger 10,000-Lb. Trolley Bus	30-Passenger 10,000-Lb. Gasoline Bus
Maintenance of Way and Structure	3.0	2.0	0.7	0.0
Maintenance of Equipment	3.4	1.7	4.0	8.5
Power	5.9	2.5	2.3	7.0
All Other Expense	19.0	12.0	12.0	12.0
Total Operating Expense	31.3	18.2	19.0	27.5

far outweigh its saving in fixed charges. Under such conditions, it can only continue to operate by evading the responsibilities of good service and not attempting to provide the necessary extra equipment for handling properly the morning and night traffic peaks, for which every traction company is expected to equip itself.

Table 3 gives a comparison of the operating costs per car-mile for the four classes of car. The rail-car data are the average of the actual records of a number of companies using both safety cars and double-truck cars; the gasoline-bus costs are derived from the records of five representative bus companies.

The costs of the trolley bus are assumed to be the same as those of the safety car and the gasoline bus as regards transportation charges and general expenses; its maintenance of way and structure covers repairs and renewals on the overhead-trolley lines only; its maintenance of equipment is based on the body and the chassis and the tire expense of the gasoline car, and the motor and the control maintenance of the safety car. For instance, safety cars on the average cost only 1.7 cents per car-mile to maintain, of which only about 0.6 cents is for repairs to the electrical equipment. The gasoline buses cost on an average 8.5 cents, of which 2.0 cents goes for the maintenance of solid tires, 1.5 cents for the body and the truck, and 5.0 cents for the engine and the transmission.

The trolley bus would presumably have the same cost for tires, body and truck upkeep, but only 0.5 cents for the motors and the control, making its total maintenance 4.0 cents per mile or 4.5 cents less than that of the gasoline vehicle.

On the power account, due to higher friction, the trolley bus will take more power per ton-mile than the rail car, but its lighter weight will somewhat more than offset this and make its total power-cost a trifle less than that of a safety car. A gasoline bus weighing 10,000 lb. in frequent-stop service can make only about 4 miles per gal. of gasoline, or 5.5 cents per mile, and the oil and the grease cost about 1.5 cents additional; it has therefore a total power expense of 7.0 cents per mile or 4.7 cents more than the trolley bus.

Numerous additional tables are given in Mr. Thirlwall's article showing investment, fixed charges and operating cost for different service conditions, varying from very heavy to very light traffic, from which the conclusions stated at the beginning of the article are drawn.

APPENDIX 3

Quotations from Walter Jackson's lengthy article entitled The Place of the Bus are given herewith.

> The advantages of the motorbus are rarely displayed by the irresponsible jitney operator, for the reason that the conditions for which buses are most suitable are rarely self-supporting from the basic standpoint of capacity or volume of business. The jitney operator, therefore, prefers to poach on the traffic that has been built up by the electric railway along definite channels after years of effort. On the other hand, if the true applications of the bus are exploited by the street-railway company itself, two desirable results ensue; isolated or remote sections really will receive service and such services, although rarely self-supporting, will often help to produce large savings in the railway department and so throw off an actual over-all profit.
>
> British tramway trackage is puny in comparison with American trackage for the same populations. . . . Among these reasons are the practical absence of formerly competitive trackage and of premature or speculative extensions into open country. Another reason hardly touched upon at the time, was that for the last decade or more no British road has built a track extension into thinly peopled territory if it could secure the right to build up such districts through a bus service first.
>
> Approximately 29 electric railways in the United Kingdom are owned and operated as individual companies by the British Electric Traction Co. Of these, about one-half operate motorbus services.
>
> Most of the British Electric Traction Co. services are of suburban character. Where tramway and bus route overlap from the center of a city up to or near the end of the car line, an extra high fare is charged to keep the facilities of the motorbuses for the long-distance suburban riders for whom they were inaugurated. In the opinion of this company's officials, the time for the tram is when the business has grown to the point of justifying, say, a 10-min. headway.
>
> An idea of the importance of the British Electric Traction Co.'s bus operations can be gleaned from the fact that for the fiscal year ended Dec. 31, 1918, it operated on the systems named close to 300 buses and carried on them 19,000,000 passengers, exclusive of those carried with 700,000 bus-miles in the London district of the British Automobile Traction Co. for which no "passengers-carried" data are available.
>
> The references to the bus undertakings of the British Electric Traction Co. are sufficient to establish the fact that the coordination of the car and the bus is not a chimera. In addition to these privately owned coordinated services, the United Kingdom has a larger number of privately owned all-bus systems, ranging from tiny rustic livery undertakings and feeder services for steam-railroad stations to the enormous system of the London General Omnibus Co.
>
> In the year 1918, the buses of London carried the impressive number of 682,000,000 passengers; the underground lines carried 699,000,000 passengers and the street railways 992,000,000 riders, although the cars have but two good points of contact with the business and the pleasure area of the world's metropolis.[10]
>
> Although British unit costs are different from our own, there is much that can be learned by studying comparisons of car and bus operations in Great Britain, particularly where the figures relate to the respective operations in the same community and under the same management. These figures will show that, wherever the services are coordinated instead of competitive, the number of passengers per vehicle-mile is usually much less on the bus than on the car, clearly indicating that the buses are being used for light-traffic routes. Furthermore, the earnings per bus-mile and the receipts per passenger are generally in excess of like classifications on the electric railway, because the average ride on the bus is longer and the rate of fare on the bus is higher. The schedule speeds of the buses are almost always higher than those of the cars, not on account of superior flexibility or higher maximum speeds, but because the buses average fewer stops per mile and have a much larger proportion of their runs in suburban territory or open country.[11]

To develop the possibilities of the coordination of motorbus operation with electric-railway lines to serve as feeders for interurban lines, the article states that the Stone & Webster interests made several applications in the State of Washington in 1915. The motorbuses were withdrawn in three instances after periods of service varying up to 18 months on account of operating losses. Quoting from the article[12] again

> The lesson to be drawn from these unsuccessful efforts to tie bus and interurban together obviously is that no such form of transportation can be successful if there are not enough customers to go around, if competition is unrestricted and if the direct bus service

[10] See *Electric Railway Journal*, Feb. 28, 1920, p. 424.
[11] See *Electric Railway Journal*, April 3, 1920, p. 683.
[12] See *Electric Railway Journal*, April 24, 1920, p. 849.

is preferable, whether from a time, money or comfort standpoint, to the use of two kinds of transportation. The amount of traffic carried did not justify the service, even after the bus is credited with bringing some patrons to the interurban. At the same time, if the bus did not make any money for the railway it had the important, though negative, virtue of preventing it from losing far more on the construction of a track and line for the distance under consideration.

It is also clear from these experiments that so long as irresponsible, free-for-all competition is permitted, the public will not enjoy that reliability of service and liability for accidents that are possible only through an established transportation undertaking.

The fourth, and surviving, route served by the Stone & Webster interests is of entirely different character, its purpose being to afford a through bus service between Seattle and Bothell, Wash., a distance of 16 miles over well-paved highways. This line was opened in November, 1915. Up to June 26, 1916, it had to compete with a five-car company, but by Oct. 10, 1916, the last jitney operator had disappeared. The Seattle-Bothell route is an example of a clean-cut bus-line from a large city to rather distant outlying communities that have no electric-railway service.

A significant fact is that few users of this route took advantage of the 5-cent fare and free-transfer privilege that would have enabled them to save money on the 5 miles between Cowen Park and the city depot at Fifth and Pine Streets, within Seattle. Consequently, the inter-line arrangement with the Seattle electric railway, then under the Stone & Webster management, was canceled Aug. 1, 1917.

This is in accord with much British experience. Most of such passengers from outlying communities desire to reach the heart of the city as quickly and as conveniently as possible rather than go through the bother of transferring from one vehicle to another at the terminus of the trolley line. Where a higher rate of fare is charged on the bus than on the car, a procedure necessary in any case, the bus will not be slowed down too much within the city through use by short-ride passengers, while the facilities remain available for the out-of-town riders for whom the buses were specifically installed.

Further installations in other sections of the Country are described also in the article, and it is stated that

> Experience abroad, and here as well, indicates, however, that people will pay a higher fare on the buses if the latter can offer noteworthy advantages in speed because of long non-stop runs.
>
> Within the limits of this article it is not practicable or desirable to list all the cases where electric railways have instituted bus services either directly or in cooperation with realty-development companies, manufacturers and other parties, but one may say confidently that today both roads and vehicles have improved to the point where requests for service to thinly peopled districts can be best and most cheaply satisfied by the installation of the motorbus.[13]
>
> The necessity for electric railways to concern themselves with the motorbus and its possibilities is clear from the dire situation that has arisen in New York City. As the reasons for the municipal bus-service there may not be so well understood outside of New York City as they are to residents of that city, a brief survey of this development may be clarifying.
>
> The greater part of the electric-railway mileage in the Borough of Manhattan, New York City, is on the underground-conduit system. This system, compelled by city ordinance, was much too costly for the electrification of certain routes that had lost their traffic importance with the decline of the ferries. Indeed, by 1913 several miles of practically hopeless trackage had been removed from the streets by order of the city. This year also marked the substitution of the storage-battery car for the horse car on such unelectrified trackage as remained.
>
> At no time did these storage-battery cars make any money, even when operated under such modest conditions as those of the Third Avenue Railway System, which used both new cars and rebuilt horse-cars. In May, 1916, when this company was operating the now defunct 28th & 29th Street Crosstown Railway, the operation and depreciation expense of a 16,000-lb. 24-seat car was 29.1 cents; whereas, the revenue was but 20.9 cents. This cost might have been brought nearer the point of subsistence if these cars had been operated with but one man each. The city ordinance that barred this practice with a slow car traveling on a fixed route does not apply evidently to the operation of the faster jitney buses that can twist and turn at will.
>
> With the further increase in costs due to the war, the New York Railways Co. in particular, found the burden of these storage-battery lines too great to bear at a 5-cent fare. Application to permit certain discontinuances therefore was made by the receiver on Sept. 19, 1919, before Judge Mayer of the United States District Court, Southern District of New York. The application was granted at once, with the result that on Sept. 20, 1919, the Madison Street, Sixth Avenue Ferry, Avenue C and Spring-Delancey Street routes ceased to function. The answer of the city administration was the installation of a "scratch" bus service, which, despite obvious shortcomings, has given the public more and faster service than was received before. The fare remained at 5 cents; but, as will be pointed out later, this is made possible only by a tax on the community as a whole.
>
> A portion of the Spring-Delancey Street line was restored Feb. 1, 1920, chiefly for transfer reasons, but it is doubtful whether the other routes ever will be. The fact must be faced that the railways on these and similar streets have become obsolete. Storage-battery two-men-per-car operation had proved both too slow and too costly to justify frequent service in territory where almost all of the traffic was of a short-ride character. The narrowness of some of the streets traversed had also been a factor in discouraging a renaissance of these lines following the elimination of the horse car.
>
> All in all, then, the policy of substituting motor-buses for the cars was the only correct one from a transportation standpoint under the conditions as they existed. It is doubtful whether any increase in fare would have done the railway operators any good. While a proposition from them to operate buses might have met with more favor, a higher fare than 5 cents would have been inevitable, since the cost per seat furnished is at least as high on a bus as on a battery car.[14]
>
> In the early days of the jitney it was fondly believed that liability bonds, taxation and other imposts would make the continuance of such operation impossible. As a matter of fact, the small touring-type jitney has largely disappeared, but it has been replaced by the more formidable jitney bus. So long as such buses are individually operated and run only on choice routes and during choice hours, their owners can show enough above actual costs to keep in the business. When investigation discloses that the same men have stuck to the game for 2 or 3 years, it is time to give up watchful waiting or passive resistance as good policy.
>
> Probably no city offers a better example of the jitney bus's tenacity than Newark, N. J. From 171 vehicles in June, 1916, to 402 buses in December, 1919, is one record; from 8,195,591 passengers in 1917 to 36,895,010 passengers in 1919 is another. These figures are de-

[13] See *Electric Railway Journal*, April 24, 1920, p. 850.

[14] See *Electric Railway Journal*, May 29, 1920, p. 1088.

rived from the reports made by the jitney operators to the city's treasurer when they pay monthly 5 per cent of their gross earnings, exactly as the railway does. As the city has no means for checking these reports, it may be guessed that the actual jitney traffic is many millions in excess of that reported.[15]

Bridgeport, Conn., with a population of 180,000, is another city where the jitney bus and the flivver have prospered exceedingly at the cost of the railway. It is still more favorable territory than Newark, because the intermingling of the factory and the residential sections with the business district between gives a remarkable amount of two-way loading, and because the jitney drivers wisely confine themselves to those fat routes which are within 4 miles length overall. Bridgeport is such a wonderful riding town that the daily riding index is almost unity; that is, there is one ride per diem per inhabitant.[16]

We have seen that more than 15 years of motorbus operation in Great Britain has not yet led to legislation that places the electric car and the motorbus on the same plane of responsibility and taxation. It must not be assumed that this delay is due altogether to national inertia and that we Americans will settle our motorbus problems overnight. The fact is that the omnibus covers so wide a range, from the simple job of hacking from a railroad station in connection with each train to functioning exactly like a street railway, that adequate yet fair legislation is really difficult. A regulation concerning liability bonds, for example, might be absolutely fair and necessary to curb a city busman and, at the same time, be most unjust to the rustic operator who wants to give the public something better than two trains per day.

The fact that individuals can often run routes for less cost than a large organization discourages the formation of the latter, thus making regulation much harder. For example, a company with an established system of accounting could not readily deceive the municipality on so simple a matter as paying a fixed proportion of the gross receipts into the city treasury. On the other hand, it is impossible to supervise the doing of hundreds of individual operators, not only with regard to their earnings but with regard to their compliance with essential service and safety regulations. The individual ownership of the buses and the condition that they, at least temporarily, enhance the transportation service of the community also lead to a measure of public sympathy that makes motorbus legislation unpopular and its enforcement difficult.

Historically, of course, the bus is derived from the stage coach and the cab. In the old days all of these vehicles operated at fares and under conditions so different from those obtaining on horse and steam railways that no one thought of placing the two public services in the same category. But while the horse bus had to give way to the horse car, the wonderful improvement of the internal-combustion engine, the development of the rubber tire and the advent of smooth, durable paving have made the line of economic demarcation between their power-driven successors much less distinct.

If, for example, the street car charges 5 cents and is available at 5 to 20-min. intervals for 20 hr. per day, it will suffer no harm whatever from a motorbus service that charges, say, 25 cents for a like distance and that is available only during hours that the operator himself selects. In this case it is clear enough that the busman is really a hackman and naturally is subject only to those demands concerning character, license and safety of vehicle that have been characteristic of stage operation.

Mark now the change in his status if he decides that it is more profitable to carry more passengers at the street-railway rate. He is no longer a hackman, temporarily renting his vehicle for the exclusive use of the first patron or group of patrons. His vehicle becomes an omnibus, literally a carry-all, whereby he not only cuts deeply into the earnings of the street railway but is also morally bound to accept the same obligations and burdens as the street railway.

The many novel problems involved in this transition, with its concurrent appeal to the public's appetite for low-cost service regardless of high-cost prices, are only now nearing solution in Great Britain. Yet the electric railways of Britain, so largely municipalized, did not have to meet the "Here's a chance to get square" tactics that are characteristic of conditions here. It simply has proved easier to control an industry that has a fixed track with some claims to right-of-way than one whose pathway is the common road.[17]

In spite of the commendable cooperation that has been manifested recently between electric railways and civic committees, notably in the cities served by the Eastern Massachusetts Street Railway, there is no reason to expect the permanent elimination of the competitive bus through any other tactics than the giving of headways that are short enough to wipe out the jitney driver's margin of profit.[18]

The argument is developed in the article that the responsibility for all mass passenger-transportation should be placed on one agency only.

In the article it is shown that practically every kind of motorbus operation costs more than modern car service on a well-traveled route, proving that at present costs the bus may supplement but cannot, from an economical point of view, supplant the electric railway upon the basis of equal fare and responsibilities. In concluding this survey of the place of the motorbus, Mr. Jackson summarizes the position of affairs as follows:[19]

(1) No service duplicating railways should be operated except for traffic-relief purposes

(2) Such service should be given by the local railway system

(3) Higher fares should be charged, preferably on a distance basis, wherever the bus offers superiority in speed and accommodations and also wherever it serves districts that are too sparsely settled to justify a permanent way

George A. Green, at the time general manager of the Fifth Avenue Coach Co. of New York City, in an article on Motorbus Transportation in New York City,[20] after describing the organization of that Company, makes the following observations in relation to the future possibilities of the motorbus:

> It already has been pointed out that motorbus operation is a comparatively new art. The possibilities of improvements are practically unlimited. This applies to design for greater comfort and convenience as well as to economy of operation. The bus requires a minimum investment in garage and repair facilities, and its low unit cost is a powerful argument in favor of its adoption. Unquestionably, if a motorbus service is to realize its possibilities of financial success, it must be backed up not only by ample resources but it also must develop a highly specialized organization. The engineering force and the management must have specialized experience, for the motorbus traffic-demands are distinctly special.
>
> Employes must be trained in a branch of motor-vehicle operation with many distinct and unique peculiarities, for which the operation of neither the auto-

[15] See *Electric Railway Journal*, May 29, 1920, p. 1090.
[16] See *Electric Railway Journal*, May 29, 1920, p. 1091.
[17] See *Electric Railway Journal*, July 3, 1920, p. 11.
[18] See *Electric Railway Journal*, July 3, 1920, p. 12.
[19] See *Electric Railway Journal*, July 31, 1920, p. 218.
[20] See *Electric Railway Journal*, July 24, 1920, p. 175.

mobile nor any form of transportation affords suitable experience. One of the chief differences between the bus and other forms of transportation is the matter of flexibility. As a matter of fact, we prefer to train men for drivers who have never had automobile driving experience. Furthermore, we find that railroad operatives, while they possess useful knowledge, must forget so much that, on the whole, it is more satisfactory to employ men without this experience.

In my opinion the wisest policy, both from a financial standpoint and the service results to the city, is to entrust a single, well organized and equipped company, possessing ample resources, with the development of a unified motorbus service. Parceling our streets to two or more companies will never provide the Pullman-car service that the true motorbus can give. The actual result of any form of competition must be multiplied fares and no transfers. With a unified system there can be no harmful monopoly, for the fare should be determined by the authorities and the company should be under public regulation, but so-called competition from a public-utility standpoint means bad service and financial failure. Cities cannot be prosperous without efficient utilities and utilities cannot be efficient without prosperity.

Clearly, where car tracks do not already exist, the most careful thought should be given before they are installed. Apart from this, from a public service as well as an operating point of view, there can be no question as to the possibility of using buses for (*a*) extending the service of existing car lines by bus system into the outlying districts through the introduction of transfer privileges between the two and (*b*) extending service, the conditions of the streets permitting, into the outlying districts without transfer service between buses and cars and without disturbing the present local business or business logical to the existing car lines, by permitting the buses to operate beyond the present outlying terminus of street cars and by diverting the buses to other parallel routes after reaching such outlying terminus.

APPENDIX 4

Under the title Teuton Trolleys Handle Freight, and a sub-title War Experience and Higher Costs for Fodder and Fuel Expected to Extend the Use of German and Austrian Tramways, the following[21] is stated:

A recent paper by Wilhelm Neumann, councillor, Austrian State Railways, read before the Austrian Engineering and Architectural Society, discusses encouraging possibilities for the further development of freight haulage on street railways. At the opening of the World War, the Vienna tramway system installed a track connection with one steam terminal to take over the passenger traffic released by the closing of the Stadtbahn to such business. The next step was to make use of these connecting tracks for freight.

The pressure for freight haulage on the street railways of Germany evidently was less, for it was not until December, 1916, that the War Department sent out a questionnaire to learn their facilities for freight business. Such business was less of a novelty to the German than to the Austrian electric railways. The latter had handled freight only spasmodically, whereas the Germans, as long ago as April, 1903, were moving freight on 60 of the 148 tramways in the country. Others were not doing so purely because of franchise restrictions.

In those days, also, the cheapness of horse transport and the cost of rehandling were the limiting factors. However, by 1913, 60 out of 135 Prussian street railways and 19 of the railways in the other German states were handling freight. These 79 companies then had 2600 cars for package mail and freight, of which 964 were regular freight cars, averaging 6 metric tons (6.61 net tons) each in capacity.

CONCLUSIONS REACHED BY GERMAN ROADS

According to chief engineer Winkler of Charlottenburg, Berlin, the German roads before the war had reached the following conclusions on the subject of handling freight:

Street railways should be considered freight feeders to the steam lines and should have direct or indirect connection with them. Car interchange is impracticable because of the sharper curves, smaller clearances, narrower wheel treads and coupler differences of the street railways. The use of sub-trucks, even if clearances are ample, is of but limited application. Trans-shipment is then necessary, and for this labor-saving devices should be used as much as possible. The freight was usually hauled in a train consisting of one motor-car and two or three trailers. Most freight service was handled at night.

The war led to a tremendous development of trolley freight. In February, 1918, practically all haulage on the electric lines was with trailer cars. In some cities garbage transport was instituted. Dusseldorf was the only city in which a package business was conducted. Most of the roads confined their efforts to carload transfers between the steam railroads and large shippers. Generally, the freight trains were run at passenger-car speeds and were often interpolated with passenger service. A disadvantage found with wagon trailers on their own wheels was the low speed of 4 to 8 km. per hr. (2½ to 5 m.p.h.), compelled by the character of their spring-suspension and brakes.

The tariff changes are usually based upon the capacity, not actual load, of the trailer and the distance run. The prices are considerably below those charged for horse drays. An auxiliary saving, due to easier transfer from steam to electric cars, is the quicker release of the steam cars, made possible by the better use of mechanical transfer-devices. More freight business by electric railways would not only enlarge the steam-railroad revenues but give a better use factor of men, powerplant, truck and line.

HEAVY WAR TRAFFIC IN VIENNA

Referring to Vienna, Mr. Neumann said that up to February, 1918, the local street railways had made 110,000 car trips, the equivalent of 310,000 wagon trips. For the same amount of work 350 horse trucks or 100 motor trucks would have been needed. A great variety of materials was handled, the local distribution of mail being especially successful.

[21] See *Electric Railway Journal*, May 22, 1920, p. 1062.

Discussion of the Chicago Tractor Meeting Papers

THE discussion of the papers presented at the Chicago Tractor Meeting of the Society included written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, are included in the discussions. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with a minimum of effort.

THE GENERAL-PURPOSE FARM TRACTOR

BY C. M. EASON

THE author divides the history of the application of mechanical power to farm work into three periods, reviews each one and comments upon the various phases of progressive development that influence the type of tractor most desirable for satisfying present needs. The requirements of farm work are outlined, and the different types of tractor built and being constructed to meet these demands are reviewed, discussion of large versus small tractors, type of drive, power needed, control, methods of operation and the factors constituting general-purpose service being included.

So far as adopting the tractor for farm usage is concerned, the author believes that the present limitation of such utilization lies with the tractor industry and with tractor engineers, rather than with the farmer.—[Printed in the June, 1923, issue of THE JOURNAL.]

THE DISCUSSION

N. S. JOHNSON:—We began with the idea that it is possible and practicable to make a general-purpose tractor; that we could develop a power machine and the implements that go with it so that the operator could attach and detach them quickly, the idea being to increase the production per man to the greatest possible extent and to reduce the cost. After several years we found we were getting very complicated machines. When the power machine became heavy enough to do some of the heavy work, it was too heavy and powerful for some of the lighter jobs. There were limitations as to the weight of the machine that could be used profitably in horticulture. A machine that would cultivate row crops to the best advantage was too light for some of the other farm work. Finally, we developed a power machine to which present horse-drawn types of implements can be attached, such as cultivators and other special equipment, that are very much lighter and cheaper to produce than are regular horse-drawn machines. We believe we have made some progress, but we have not by any means reached the point where we think the problem has been solved; it is a very intricate problem.

CHAIRMAN A. W. SCARRATT:—If we are to extend the uses of power farming, we must make the power unit applicable to the present horse-drawn implements. Another phase concerns the question of whether present horse-drawn implements are capable of withstanding the severe operation they must endure when pulled by an inflexible power-unit. A power-driven unit is not flexible in the sense that a horse is. To attain this ultimate result will require cooperation between the manufacturers of the power unit and of the implements. The Farm Equipment Association and the tractor builders must correlate their views.

DENT PARRETT:—Our experience with light cultivating machines was gained on a large farm. We found that our small machine could be kept busy almost every day of the summer; a larger tractor on the same farm was used only for a few days. This gives an idea of the comparative utility and demand for a machine that can be used for all the other operations. Some things are done ordinarily with two and three-horse teams; the lighter work, such as cultivating and haymaking, can be done with the light machine. A tractor to do this work must be well made, because a general-utility tractor would run several times as much per year as the tractors we have now.

CHAIRMAN SCARRATT:—Farming requirements vary according to the district; in the large grain-producing sections in which there is little diversity of farming and in which large acreages must be covered, our present tractors nearly fill the requirements of the farm. Even a three-plow tractor, and surely nothing larger than that, would not be a profitable size of machine to use for diversified work. What we must think about is the creation of a new small-size machine of not more than two-plow capacity that will do a wide variety of work. The increased number of hours of use that a light machine would have and the necessity for high-class construction to make it able to withstand this increased service are important matters. The cost of the machine will increase with the increase in quality. Whether it will be possible to bring out a flexible light-weight machine and sell it at such a price as will make it a real competitor with present power and horse-drawn implements will require serious study.

J. B. DAVIDSON:—So long as the corn-belt farmer must use animal power to cultivate and gather his crop, he will not find a very large place for mechanical power. The solution of the problem depends on taking into account some of the most important factors involved, one of which is the realization that the cultivation of corn is a precision operation. A tractor cultivator must go just where the operator wishes it to go without any doubt; dangling lines, flexible connections and the like, are a disadvantage. Four rows of corn can be cultivated in one operation just as well as two if the four rows have

been planted in one operation. There is also a possibility of employing better farming methods. With plenty of power there is little reason that weeds should start in the corn field. The main purpose of cultivating corn is to kill weeds.

C. C. TRUMP:—I agree that the steam tractor as it was is on the decline, but it seems that there still is a place for the steam tractor.

C. M. EASON:—About 12,000 or 15,000 large-size tractors for threshing and for similar work are being built each year; it is a steady business.

MR. TRUMP:—I referred to something a little different from the ordinary conception of the steam tractor. Having to do with uniflow steam engines, I have had an opportunity to cooperate with one of the tractor companies in developing a light steam tractor. We designed the engine for it, after having designed the engine for a truck. We found that, although there were difficulties with the engine, the main difficulty was with the boiler and the combustion system. Development work of this kind has been going on for about 10 years.

It has been suggested that, since we must consider the fuel problem, the waste products of the farm should be used for fuel. A steam boiler that is properly designed will burn wood, straw, corn, oil or coal. If the average use of the tractor is only 50 days per year, we must consider ways to reduce the interest charges by increasing the use. It would seem to me that the steam tractor could be used during the winter for furnishing power, light, hot water and, by proper connections, could store heat for houses. We all are familiar with the possibilities of the flexibility of control of steam power for cultivating and for work of that kind. It seems to me that such a tractor could be worked out, and that there are possibilities in this direction that engineers have not taken into account. The types of engine, boiler and combustion system are being improved and I believe are available for a light machine, suitable for two or three plows and general-purpose work.

A MEMBER:—I am interested in the light-type steam tractor. We have found that the steam-power tractor using distillate or low-grade fuel works satisfactorily under high-pressure steam.

CHAIRMAN SCARRATT:—The steam tractor certainly offers interesting opportunities for further development in the future.

NEBRASKA TRACTOR-TEST ANALYSIS

BY OSCAR W. SJOGREN

A COMPILATION of all results of the tractor-testing work at the University of Nebraska is presented by the author, who specifies the equipment used and discusses the subjects of the proper rating of tractors, belt speeds, weight distribution, tractive efficiency, wheel slippage, piston displacement, fuel and water consumption in considerable detail supplemented by illustrations. The defects of tractors are divided into the three main groups of engine, accessory and chassis, and enumerated, comment being made thereon.

Three general recommendations for remedying these defects are stated and a statistical record of the results secured during the three seasons when the tests were conducted is included. That a better product is one of the direct results of the testing program is indicated by the statistics presented in Table 1.—[Printed in the June, 1923, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN SCARRATT:—Professor Sjogren's paper is distinctly divided into two parts; one pertains to the graphic analysis of the Nebraska tractor-test results from a design standpoint; the other is a statement of the nature of the troubles encountered during the test. How many builders sent their experimental machines there to get an idea of what the machines could do? The number of troubles and their variety are such that the builders and their engineers should profit by them. Judging from the decrease in the kinds of trouble encountered in 1921 and 1922 as compared with 1920, they have done so.

I am impressed by the relative drawbar efficiencies of tractors, with respect to tractor weights. Undoubtedly, many of the tractors that made the best relative showing probably can attribute a good share of it to a wise selection of drive-wheel equipment. The preparation of the track on which the drawbar testing was done has a bearing on the efficiencies recorded during the tests, and the difference in tractor ratings when machines of different companies are equipped with the same make and size of engine is definite proof that there must be some standard basis of tractor rating; it is not logical or fair to the farmer that machines which are driven by the same make and size of engine should carry different ratings. The difference in efficiency due to transmission design does not warrant any extravagant claims on the part of any builder as to the performance of his machine. Gear-driven machines versus live-axle-driven machines should be discussed, as well as Professor Sjogren's chart showing the relative efficiencies of the different types of engine, particularly the common L-head type as compared with other types.

H. A. HUEBOTTER:—Fig. 1 of the paper shows that, on the basis of the proposed horsepower rating of 80 per cent of the maximum power, the belt rating of about 70 per cent of the tractors tested must be reduced. On the other hand, the drawbar rating of only 30 per cent will have to be lowered. Three things may have some effect on the drawbar rating in proportion to the belt-horsepower rating. In the first place, the builder has not the opportunity for measuring drawbar horsepower to the same degree of refinement that he can measure engine power in a laboratory. Hence, he is conservative in his drawbar-horsepower rating to be on the safe side. Secondly, the tractor may have been limbered-up more for the Nebraska tests than it would be for field tests around an experimental farm or at the factory. The third point, which affects the mechanical efficiency of the tractor from the engine to the drawbar, concerns the power losses between the wheel and the ground. We can deliver considerably more power to the wheels than we can get at the drawbar. The difference between the power at the wheels and that at the drawbar is usually known as the ground loss. It may consist both of slippage between the wheels and the ground and of the power required to move the tractor.

What is Professor Sjogren's estimate as to the field conditions of soil that are approximated in his composite track of earth and cinders? What field conditions would require the same power to run the tractor idle as

would be encountered on the track, and just what conditions would give the same slippage at full load as would obtain on the track? If I understand correctly, slippage is based on the distance traveled if the lugs do not cut into the ground. Is that correct?

PROF. O. W. SJOGREN:—Yes.

MR. HUEBOTTER:—On that basis, there will be some apparent slippage if the lugs enter the ground at all. If the tire rides directly on the ground, slippage will be reported even if there is no actual shearing of the ground. With regard to data on the development of the power rating for tractors, what is the horsepower in terms of cubic inches of piston displacement per minute?

PROFESSOR SJOGREN:—That was brought out in Figs. 17 to 19. Regarding the comparative ground condition in the field that would about equal the ground condition of the track, that is practically an impossible question to answer because field conditions vary so much. Tractors go over our track time and again; this chews it up to such an extent that we do not get actual field conditions. To counteract this, we attempt to unify the conditions as much as possible by the use of drags, harrows and packers, whenever we feel it is necessary. We do not use rollers, packers or harrows in all cases or at all times; their use depends on the condition of the track with regard to moisture and compactness. Roughly speaking, the condition of the track during the tests might be represented by a plowed field with the surface in medium condition as to hardness or compactness with the lower part fairly compact.

MR. HUEBOTTER:—Is it more like a stubble field than sod?

PROFESSOR SJOGREN:—Yes.

CHAIRMAN SCARRATT:—We can all appreciate the difficulty of maintaining a uniform track, because nothing is any more variable than the fields that tractors work in, due as much to moisture content as to anything else. As to piston displacement as a basis of rating, that would seem to be unreasonable in view of the wide variation that exists in the piston displacement per horsepower delivered of the different engines that have been tested. It sometimes seems almost ridiculous to assume any piston-displacement as a basis for judging the horsepower of an engine, because there are such great differences in the performance of engines.

We have a criticism pertaining specifically to the methods of determining drive-wheel slippage, followed in the Nebraska tests. Professor Sjogren has stated that drive-wheel slippage is based on the outside diameter of the wheels with the lug equipment attached. With that in mind, we never could attain 100 per cent traction because ever so little penetration of the wheel equipment into the ground would show up as a certain amount of slippage. Whether or not his future work should consider a diameter of less than the maximum outside diameter is a point that we should determine. In calculating the traveling speeds of tractors, it is customary for most builders to consider the outside diameter at the drive-wheel rim as being the diameter to use; assuming that the lug equipment does not penetrate, the amount of grip is obtained in that way.

Concerning the method of determining slippage by counting the revolutions of one drive-wheel without consideration of the revolutions of the opposite drive-wheel, there is a question whether that is a proper way to determine the distance traveled and the amount of slippage.

R. F. VOGT:—A most serious error in testing drawbar horsepower at Lincoln, Neb., was made by the official testers in counting the revolutions of only one tractor drive-wheel to judge engine speed and slippage. In all Nebraska Official Tractor Tests made in 1920 and 1921, at Lincoln, the revolutions were counted on one drive-wheel only, thus neglecting the action of the differential in the tractor which, of course, makes it possible for one drive-wheel to slip more than the other when the tractor is pulling a heavy load on the more or less hard surface of the test track. The engine speed was calculated from the revolutions of one drive-wheel and the gear ratio of the tractor. As the drive-wheel on which the revolutions were counted slipped more or less than the other, this may have caused the calculated engine speed to vary from the actual speed.

PROFESSOR SJOGREN:—In the present method of conducting the maximum drawbar test the time and slippage observations are taken between stations 400 ft. apart. The time is taken by a stop-watch and the number of revolutions of the drive-wheels is secured by electric revolution counters, one of which is mounted on each drive-wheel. An electric speed-counter attached to the engine and with its indicator mounted in the testing car is used for observing the engine speed. The governor is set to allow the maximum power or full throttle-opening. The load is adjusted so as to keep the speed of the engine at approximately the rated figure. This enables us to secure much more accurate results than was possible before these improvements were installed.

Table 2 is a record of drive-wheel revolutions in 400 ft. as taken from the log sheets of several tests run after the counters were installed.

MR. VOGT:—The test track at Lincoln that was used for the Nebraska Official Tractor Tests was, in my opinion, very unsatisfactory insofar as presenting uniform conditions for all the tractors tested. To get the greatest satisfaction, the test track should have been plowed-up after each test run, especially after testing very heavy tractors. This was not done and consequently some light and some medium-weight tractors showed greater slippage than did others of the same weight and wheel equipment.

TABLE 2—NUMBER OF REVOLUTIONS OF DRIVE-WHEELS IN 400 FT.

Test No.	Diameter of Wheel, In.	At Rated Load		At Maximum Load			
				In Low Gear		In High Gear	
		Right Wheel	Left Wheel	Right Wheel	Left Wheel	Right Wheel	Left Wheel
86	*T*	29.2	29.3	30.0	30.2	35.6	34.7
87	50	32.4	33.5	32.7	33.2	32.1	34.9
88	42	37.6	35.7	38.7	39.2	42.8	43.2
89	*T*	30.6	29.8	30.0	29.9	29.8	29.9
90	72	21.5	21.5	23.0	22.9	25.6	27.0
91	42	35.4	35.1	35.9	36.7	35.9	39.8
92	48	32.0	31.7	30.7	31.6	30.2	29.8
93	56	26.3	26.4	26.8	27.6	25.9	25.6
94	60	24.5	24.4	26.0	26.9	24.1	23.7

PROFESSOR SJOGREN:—We realize better than anyone else that the testing track is not anywhere ideal and we do not want it ideal. We are required by law to test the tractor under actual field conditions or conditions approximating them, and while the track used is not the most satisfactory, a special sand clay track would be far more remote from actual conditions encountered by the farmer in the operation of his tractor.

With regard to slippage of the drive-wheel, whether it is taken at the point of the lug or at the rim, our last reports give the percentage at both the point of the lug and at its base, which is the rim of the wheel. I am not positive that either method is correct. It may be that the point of penetration should be the point at which slippage should be taken, but many variables enter. I think the two sets of figures we give are the nearest that can be obtained. Mr. Vogt's criticism did not refer to the method of determining the horsepower or its value, but pertained to the method of securing the data relating to wheel slip and the engine speed in the maximum drawbar tests, which are merely furnished as supplemental information to the reports.

As regards the counting of drive-wheel revolutions to determine slippage, we can now count the revolutions on both drive-wheels to one-tenth of a revolution. We have also installed equipment that enables us to determine the engine speed directly during the run without reference to the revolutions of the drive wheel. We have our test machine arranged so that, by electrical apparatus, the man in the machine can count the revolutions of both drive-wheels and can adjust the load to keep the engine speed at the exact rated number of revolutions per minute. These electrical counters indicate that the number of revolutions of each of the two drive-wheels does not vary more than 5 or 6 per cent; that is, the slippage does not vary more than this amount. The records were obtained under conditions of track that varied from very dry and loose to wet and are an indication of the slip during the regular and maximum drawbar tests.

The high tractor efficiencies shown in the charts are for the crawler type. We have some high efficiencies for the wheel type but not nearly so high as for the crawler type. This probably is not due so much to the equipment as to the way in which the belt power is taken from the engine.

We welcome constructive criticism of our methods, so that we can improve them. We had nothing to guide us in building equipment or in devising methods of procedure during the first two years of testing. We take advantage of every breathing spell and all constructive criticism to help us to improve conditions and equipment.

B. S. PFEIFFER:—In the charts on fuel consumption, what kind of fuel was used?

PROFESSOR SJOGREN:—Both kerosene and gasoline. The lowest figure on kerosene was 0.63 and the highest, 1.40 lb. per b. hp-hr.; on gasoline, the low figure was 0.65 and the high figure, 1.13 lb. per b. hp-hr. Very few tests are in the high class; more of them run about 1 lb. per b. hp-hr.

MR. HUEBOTTER:—Professor Sjogren has an unparalleled opportunity for seeing the relation between the brake horsepower and the cubic inches of piston displacement per minute. The big variable in the horsepower equations is the mean-effective pressure. If we get an average value of the brake horsepower from this series of tests, it may give us a chance to establish a formula for this type of heavy-duty engine. Does Professor Sjogren compute the mean-effective pressure in his test results?

PROFESSOR SJOGREN:—No; the engines are not equipped to give it. I have made an attempt, however, to figure the rating based on the cubic inches of piston displacement, but it varies so that there is no basis of comparison.

CHAIRMAN SCARRATT:—How did Professor Sjogren determine the brake horsepower of the engine in getting at the cubic inches of displacement? Is it based on the brake horsepower delivered to the dynamometer or at the crankshaft?

PROFESSOR SJOGREN:—It is that delivered at the dynamometer.

MR. TRUMP:—Were any heavy oils and fuels tested, or any steam tractors?

PROFESSOR SJOGREN:—No, if by heavy oil you mean anything heavier than kerosene.

MR. TRUMP:—Is your equipment such that you can test machines that burn heavy oil?

PROFESSOR SJOGREN:—Yes.

CHAIRMAN SCARRATT:—From the wide variation in the governor regulation, it seems almost as though some of these engines would perform better if they were not equipped with governors. What does Professor Sjogren think a governor really ought to do in the way of speed regulation?

PROFESSOR SJOGREN:—I can relate what has been done. An engine was brought there that had a speed regulation of less than 1 per cent either way from its rated speed, that is, above or below its specified speed, but that is so nearly ideal that we cannot hope for such perfection. I think a governor should maintain the engine speed within 5 per cent, plus or minus, of the rated number of revolutions per minute. We have had governors that would do that very easily.

CHAIRMAN SCARRATT:—What is the extreme variation?

PROFESSOR SJOGREN:—It is about 50 per cent.

A. H. BATES:—I believe that tractor builders have been thinking more about the rating of tractors during the last year than they did formerly. If we rate a tractor on the present S. A. E. Standards basis, that is, 80 per cent of the maximum belt power delivered for 2 hr., the rating cannot be checked easily and is not understood by the purchaser. Many builders, as shown by the 1923 tests, are rating their machines rather close to the maximum load that the machine will handle. For instance, one builder rates his engine at 30 hp., whereas its maximum output is only a trifle more than 32 hp.

The loads on the tractors with which I am familiar have been intermittent and testing an engine at the maximum or even at the rated power for a 10-hr. period possibly puts a load on the engine that the builder did not contemplate. If an electric motor designed for a certain temperature-rise for a 30-min. load is put through a 10-hr. maximum load test, it will burn out. That is one of the reasons why some of the tractors on test showed such a high water-consumption. Their radiators were designed for an average load, and the full load was put on them for the entire period.

CHAIRMAN SCARRATT:—I do not know whether Professor Sjogren's figures refer to water consumption as injected with the fuel or water added to the cooling system; one is a subject relating to carburetion and the other is a subject that relates to radiation. Radiators ought to be capable of cooling the engine adequately under a sustained maximum load, because the tractors must operate through a very wide range of temperature and of altitude conditions, and both have a very pronounced effect on the cooling capacity.

PROFESSOR SJOGREN:—Engines operating at their maximum rated capacity for 10 hr. do not, as a rule, develop the maximum horsepower on the drawbar. They usually have an appreciable percentage of reserve on the drawbar, so that the drawbar test, which is for 10 hr., does not strain the tractor unduly and the fact that it is out in the open is also conducive to good operation. The 1-hr. maximum belt test, as well as all belt tests, is conducted in the testing laboratory and although we provide a good circulation of air, the tractor does not get so good cooling as it would outside. Regarding the water consumption, the tractors that are coming in now show a decided improvement over those that came in last year. It is just a matter of getting adequate radiation surface to dissipate the heat.

J. L. RECORD:—The buyer is entitled to know the rating of a tractor from both the drawbar and the engine standpoint. He is entitled to have it based on something that he can check himself to determine whether the tractor is rated properly. It seems to me that some simple method of rating should be adopted so that the farmer can check it.

Regarding slippage, I believe the only thing that can be fixed upon is the outside diameter of the rim of the wheel. In the early development of our tractor, we had a very large machine working in Texas in the mesquite brush and had much trouble with the differential. The machine was at work in a ditch and pulled a large grading machine. The sloping side of the ditch caused the weight of the tractor to fall on one drive-wheel. When we counted the revolutions of the drive-wheels, we found that one wheel was making 40 per cent more revolutions than the other, causing a very severe strain on the differential.

As to the engine, fixing what is a reasonable rate of speed should include a consideration of the conditions under which the engine works. If we sell an engine that we say has 40 hp., the rating should be such that, under the conditions which it is reasonable that the purchaser can maintain, he has a 40-hp. engine. I think the rating should be conservative, and that rating should apply to the power of the tractor also.

From the standpoint of the market, I think engineers should have control of the sales departments. A clever salesman can mislead a purchaser through the improper use of the technical rating of a tractor and make him think he is getting something that he is not getting. The purchaser should be able to determine the rating for himself. The rating prescribed should be one that we will all agree to use; then it ought to be possible for engineers to see that the sales departments of their respective organizations use that rating and are not permitted to use any other. The success of automobile companies is due largely to the cooperation of engineers and their advice as to what should be produced and what should be established as standard. The industry should establish standards on practical lines, talk the farmer's language so that he can understand and then make certain that the organizations adhere to them. Something that is clear and plain in the office should not be cast aside by the salesmen in the field; that is too confusing.

CHAIRMAN SCARRATT:—I am sure that all of the builders are aiming to produce a legitimate tractor, legitimately rated. The evidence of that lies in Mr. Sjogren's statement that shows the decrease in the number of tractors that failed to come up to the Nebraska test-requirements.

W. H. WORTHINGTON:—Possibly the greatest criterion of what the life of a tractor will be is the thinning of the oil by use. As I watched the tests at Lincoln, I was very much disappointed at the poor condition of the lubricating oil at the end of so short a period. We have been working on an engine in which, after 1 month and 24 days of operation at road building on kerosene, a severe test because of the variable loads, the viscosity of the oil was reduced 8 Saybolt sec. at a temperature of 112 deg. fahr. The oil viscosity was originally running 74 Saybolt sec. Regarding the tractor tests, is similar information available?

PROFESSOR SJOGREN:—No.

MR. WORTHINGTON:—Have you reached any conclusions as to the later tractors?

PROFESSOR SJOGREN:—No.

MR. WORTHINGTON:—The indications are that temperature control is gaining an important place in tractor design, the use of some system of control for the intake temperatures that will do away with a drop of temperature under lesser loads. The particular engine of which I spoke had an idling temperature, the lowest recorded, of 210 deg. fahr. The highest idling temperature is 290 deg. fahr.; the lowest full-load working-temperature is 175 deg. fahr. To overcome those conditions will solve the one great problem that confronts the user of our product toady; we can see the mechanical difficulties.

SCIENCE IN THE EVOLUTION OF INDUSTRY

LESS than a quarter of a century ago the automobile industry was in its infancy. Today it is one of the largest. The horseless vehicle had been a dream of many years. Civilization had outgrown the ability of the horse for speed, endurance and capacity. Imagine the number of horses that would be required to replace the automobiles and motor trucks of today. It was also the need for a more flexible system of local transportation that caused the development of motor-propelled vehicles. The perfection of the gas engine as the powerplant of the automobile has made possible the tractor, the household electric lighting plant and other power-driven devices. This automobile industry, too, has called for the services of the physicist and the chemist as well as of the engineer. The industry has often been impatient and forged ahead of the laboratory, but it has then usually paid the price, or, rather, the public has. The evolution of the motor vehicle has been a bold and a rapid one. The speed of it has been due not alone to the urgency of need but to the greater facilities for production granted it by previous evolutions. It has had a greater stock of accumulated knowledge upon which to draw. But it has also created new and important problems, many of which are yet unsolved. For example, the time is not far distant, if it is not already here, when the uses to which our crude-oil supply is put will be restricted to those for which it alone is suited, such as lubrication. Hence, one of the greatest problems of the industry is to find a substitute for gasoline. Internal-combustion engines are now being made to use a heavier fuel than before, and those to use crude oil are being developed. Many experiments are being made on the use of other fuels. Alcohol, if free from water, can be mixed very successfully with gasoline in large proportions. The automotive industry faces many problems in the future, but its evolution will, like the others, be brought about as the automotive engineer and the scientist work together and attack increasingly difficult problems with the more and more efficient tools of science.—From the inaugural address of S. W. Stratton, president of the Massachusetts Institute of Technology.

Wire Wheels

By W. W. DAVISON[1]

BUFFALO SECTION PAPER *Illustrated with* DRAWINGS AND PHOTOGRAPHS

WIRE wheels, having been used exclusively on bicycles, naturally were adopted as standard by the builders of the early types of automobile. But as the automobile soon increased greatly in weight and as its builders believed that the best results could be attained by wheels of large diameter, wire wheels were found to be lacking in strength and were discarded in favor of wood wheels of the artillery type, which at that time were being imported from France. When, a few years later, wire wheels again appeared on some of the English models, the prejudice against them still remained and it was not until about 1914 that they began to find favor in the industry. Drivers of racing cars, however, continued to use wire wheels because they obviated the flywheel effect and lent themselves to quicker braking and accelerating.

Attention first was given to increasing the strength of the spokes, then to their shape, so that, whereas the spokes used in the first tests could withstand only about 6000 shocks, those now in use can resist upward of 1,500,000 shocks before breaking. These results have been obtained from the 25-deg. taper, bung-head type, made of 0.205-in. wire, swaged by gradually reducing the center of the spoke to 0.148 in. in diameter and then increasing it to its original size at the threaded end. The tests that the spokes must undergo are intended to duplicate the various lateral stresses and impacts received in service.

The sudden demand of 5 or 6 years ago caused the double or two-spoke lacing and other discarded and inferior makes to be marketed, and trouble again appeared, but the difficulty has been obviated by the triple-spoke wheels now in use. In addition to greater strength and ability to resist impacts, the advantages of wire wheels are said to include quick changeability and greater tire mileage, due to the resilience of the wheels, which assists in absorbing road shocks, and to the radiating by the spokes of the heat generated by the friction of the tires on the road. The method of driving also has been improved by the use of a corrugated taper drive that is described.

ALL are familiar with the velocipede and the bicycle, and most of us can remember when the velocipede was made entirely of wood, except the axles. The first bicycle, following the general lines of the velocipede, was equipped with wood wheels, but manufacturers soon found that wood wheels were not satisfactory because of the danger of breaking and the difficulty of making a wood wheel that would give complete satisfaction without undue weight. This type of wheel was soon discarded and all bicycles were equipped with metal wheels, in which the rims were secured to the hubs by steel-wire spokes. The wheels were almost universally of the type in which the spokes are secured to flanges at each end of the hub and terminate at approximately the center of the rim. The fact that there has been no change in this feature for the last 25 years is, I believe, sufficient evidence that such wheels are the best for bicycles that can be found.

The first automobile builders naturally followed bicycle practice and equipped their cars with wire wheels of the bicycle type; but owing to the fact that the automobile developed quickly into a large heavy vehicle, and also to the fact that automobile companies believed that large-diameter wheels would give the most satisfaction, it was discovered that wire-spoke bicycle wheels did not have sufficient strength. Attempts were made to bring out a wire-spoke wheel that would be sufficiently strong, but the manufacturers could conceive of no other way of doing so than by increasing the number of spokes, which were arranged as in the bicycle wheel, or more or less fantastically. The complexity of the spoke arrangement did not appeal to the popular fancy, and as wood wheels of the artillery type were imported from France about that time, wire wheels soon dropped into disuse and automobiles, beginning about 1903, were equipped with wood wheels, the only exception being buckboards, which continued to be made for 1 or 2 years after that date. Although automobile builders found that large-diameter wheels were not suitable for motor vehicles, they still retained the wood wheel rather than take the chance of returning to the old bicycle type. So far as I have been able to determine, there was no tendency at that time to use disc wheels.

About 1910 or 1911 motor vehicles imported from England were equipped with wire wheels that had all the advantages of the old bicycle type, that is, lightness, resiliency and appearance, without its disadvantages, but owing to the prejudice against wire wheels that had been created in the minds of the automobile builders and to the wheels being more expensive than wood wheels, the wire wheel did not take hold of the automobile industry until about 1914.

However, there is one exception to that statement; namely, the use of wire wheels on racing cars. As soon as wire wheels of sufficient strength were produced, drivers of racing cars without exception adopted them, because they obviated what is popularly known as the "flywheel" effect, due to the disproportionate weight of the wheel at the rim. The wire-spoke wheel, by avoiding this difficulty, lends itself to quicker braking and accelerating. The adoption of the wheels by racing drivers soon led automobile builders to look further into the matter and, since about 1914, the use of wire wheels on motor vehicles has increased rapidly in spite of the fact that, even though great attention has been given to production methods and the cost of manufacture, it has been absolutely impossible for wire wheels to compete with wood wheels on an even basis, the wire-wheel cost being approximately from 50 to 100 per cent more than that of wood wheels.

During this time automobile companies have been improving all the other parts of their cars and replacing wood wherever possible with steel, with the exception of a single firm that continues to use a wood frame to obtain lightness. The increasing use of steel naturally has led many companies to consider that wood wheels, which today are substantially the same as those of 20

[1] M.S.A.E. Factory manager, Wire Wheel Corporation of America, Inc., Buffalo.

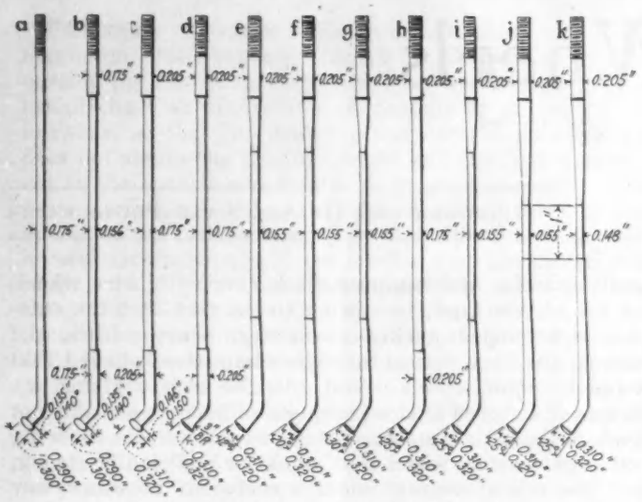

FIG. 1—EVOLUTION OF SPOKE DEVELOPMENT

years ago, should be avoided and that steel wheels should be used. To meet this demand and to avoid the expense of wire wheels, there has been a tendency to employ steel disc-wheels, which can be procured at approximately the price of wood wheels.

SPOKE BREAKAGE

The chief difficulty in the use of wire wheels for heavy cars during the pioneer days was the breaking of the spokes which was current in 1917 and rightly caused many complaints. An attempt, therefore, was made to provide spokes that would give the utmost service that could be expected of them. After several years of experimenting, testing and changing, we have developed a spoke which is, we believe, the strongest that can be made. The chemical composition, particularly the carbon-content of the spoke, was the first point to be attacked, and we soon found by physical and chemical tests that the composition of the spoke used in 1917 was not correct, but with the assistance and cooperation of spoke manufacturers, a spoke of surpassing toughness and resiliency was produced.

Fig. 1 shows a series of spokes and Table 1 represents their chronological development up to the present, illustrating the type of head, body of spoke and the like.

In carrying out the tests we developed testing-machines so that we could determine accurately the best design and metallurgical construction of spokes. Fig. 2 shows a testing-machine for applying radial torque intermittently in both directions. We found the most efficient way to test the wheel was to place it under the strains to which it would be subjected in operating the car; that is, the strains that will be met with when the clutch is thrown in and when the brake is applied. This we did by mounting the wheel so that the rim was clamped rigidly to prevent movement. The hub was mounted on a shaft that was oscillated to give the spokes the strains that they must meet whenever a car is started or stopped. The first tests showed that a wire-spoke wheel, made with the best spokes procurable at the time, would not withstand more than 6000 of these shocks before beginning to break. We soon developed spokes with which the wheel could be subjected to as many as 100,000 shocks before a spoke would break. If we should consider, which I believe would be perfectly fair, that on an average in actual operation the wheels of the car are not subjected to one of these shocks oftener than once per mile, this would mean that the wheels would be capable

TABLE 1—CHRONOLOGICAL DEVELOPMENT OF SPOKES

Index	Type	Diameter, In.	Taper, Deg.	Diameter, after Swaging, In.
a	Button-Head	0.175	None	Not Swaged
b	Button-Head	0.175	None	0.156
c	Button-Head	0.205	None	0.175
d	Special Button-Head	0.205	None	0.175
e, f, g	Bung-Head	0.205	12, 20 and 30	0.155
h	Bung-Head	0.205	25	0.155
i	Bung-Head	0.205	25 (long)	0.155
j	Bung-Head	0.205	25 (long)	0.148
k	Bung-Head	0.205	25	0.175

of giving service for 100,000 miles before difficulty would be encountered.

However, this was not believed to be sufficient and we began to consider changing the shape of the spoke, since we found that the tendency was for the spoke to snap at the head end. Up to that time we had been using what is commonly known as a button-head spoke, in which, as is shown in Fig. 1, the diameter of the spoke decreases quickly from the head to the body; and it was at this point that most of the breakage occurred. We then developed a new spoke that avoids these sharp changes of diameter and, in the tests, wheels equipped with these spokes have withstood as many as 1,500,000 shocks before the breakage started.

SPOKE DESIGN

The spoke designated in Fig. 1 by the letter *k* and from which we obtained such excellent results in our tests, is what is known as the 25-deg. taper, bung-head

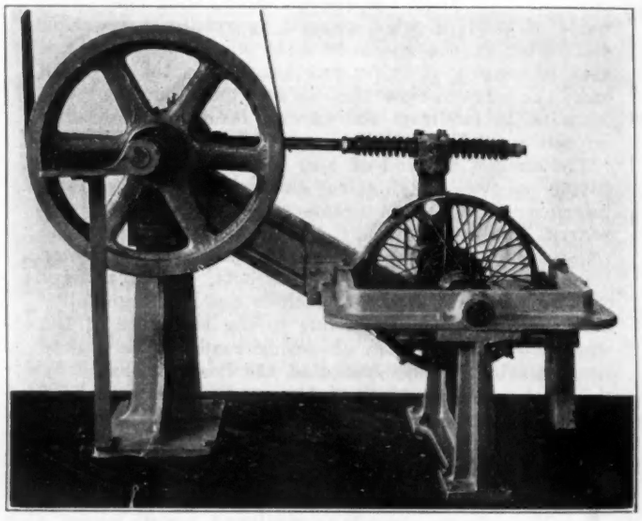

FIG. 2—TESTING-MACHINE FOR APPLYING RADIAL TORQUE INTERMITTENTLY IN BOTH DIRECTIONS

type, made of 0.205-in. wire, swaged by gradually reducing the center of the spoke to 0.148 in. in diameter and then increasing it to its original size at the threaded end. The spoke holes in the hub shell are countersunk to conform to the shape of the 25-deg. taper head so that, when assembled, a perfect taper fit is obtained. After the spoke has been put under the necessary tension at the time the wheel is built, the head remains fixed in position relative to the hub shell by having the center of the spoke swaged to a minimum diameter. The vibration is transferred from the head toward the center or blade of the spoke, which bows back and forth under the load. Hence, breakage is eliminated by transferring the vibrations to and absorbing them into the blade portion of spoke, and reversely, to the rim, thereby preventing the localizing of a fatigue point.

As the tests were intended to duplicate the conditions a car must undergo, we anchored the hub of the wheel, as shown in Fig. 3, in a side-deflection testing-machine, applying a lateral load to the rim, reproducing as nearly as possible the strains that a wheel sustains as the result of side stresses and ascertaining the lateral resiliency of the wheel. A further test is to mount the wheel and subject it to a heavy blow at the rim from a pendulum, as shown in Fig. 4, to determine its action when skidding against a curb. When this test was carried to the breaking-point it showed without question that a blow which would have put a wood wheel completely out of commission will not destroy a wire wheel. This test is perhaps the closest approximation to the blow the wheels of a car would receive in a collision, and we have found the results of the tests to be borne out by actual road service.

In spite of their excellent performance and merit, wire wheels have been subjected to a great many criticisms. In many instances they have been well founded and are just. The manufacturers themselves have been partly responsible, as the engineering departments did not develop wire wheels as rapidly as motor-car engineers developed their products.

The question of spokes was of great importance, yet was practically neglected. The manufacturers believed that by increasing the number of spokes breakage could be prevented, but they disregarded the most important part, that is, the chemical and physical analyses of the steel used for making the spokes, also the type of head to be used and the amount of swage reduction necessary to spread the vibration over a wide area and to prevent fatigue from taking place at any one point. The manufacturing tolerances were too liberal; closer tolerances could have been used, but it was easier to work to large ones that allowed inspection departments to pass products that today would be considered unsatisfactory. The sudden demand for wire wheels in 1917, 1918 and 1919 created an opportunity for inferior makes to be marketed, such as those with the double or two-spoke lacing, which was discarded years ago and which had not been designed to take care of the side stresses and strains that necessarily are to be expected in the wheels of heavy cars. The result was that spokes would loosen-up, squeak and break.

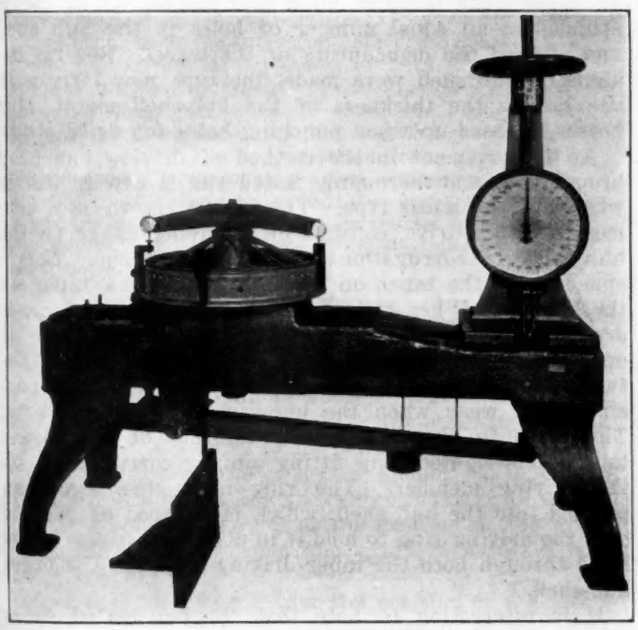

FIG. 3—THE SIDE-DEFLECTION TESTING-MACHINE DESIGNED TO REPRODUCE VERY NEARLY THE STRAINS TO WHICH A WHEEL IS SUBJECTED IN SERVICE

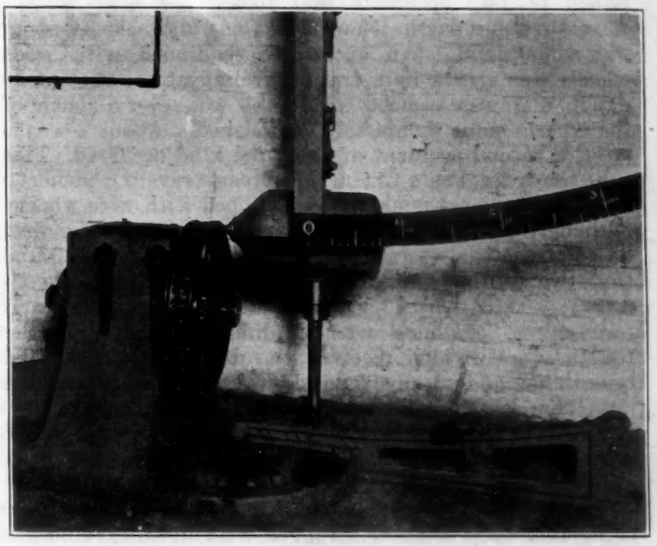

FIG. 4—THE PENDULUM TESTING-MACHINE THAT DETERMINES THE ACTION OF A WHEEL WHEN SKIDDING AGAINST A CURB

An endeavor was made to market a two-spoke wire wheel demountable at the rim and lacing through the metal felloe for a four-wheel equipment, but that type of wheel, owing to the narrow lacing zone of the felloe, did not give sufficient strength and satisfactory results could not be obtained except on light-weight cars. Wire wheels therefore were condemned by many persons; but the difficulty has been overcome by the triple-spoke wire wheels of today.

Wire wheels of the interchangeable type demountable at the hub are easier to remove, as all hub-caps are removable by unthreading them in the same direction as the wheels turn when the car is going forward, irrespective of the side of car, whether right or left. To insure the self-tightening effect of the hub-cap on the inner hub, we cut right-hand threads on hubs for the left side of car and left-hand threads for the right side. Hubs in the pioneer days of the industry were not properly identified by the maker. To ascertain the direction of rotation of a gear or of a magneto, it is customary for the observer to face the rotating member and determine whether it rotates clockwise or counter-clockwise. Many believed, consequently, that the right or the left side of the car was determined by facing the radiator. But we have always considered that the right or the left side of the car should be determined when sitting in the driver's seat. We find, even today, that the average car-owner will install the hub-caps wrong; that is, he will put those intended for the right side on the left, and vice-versa, the result being that the hub-cap, owing to the outward pressure of the wheel and the reversed threads tends to loosen and the wheels may come off. To obviate this possibility, a self-locking latch has been provided to hold the hub-cap in place, even though it may have been installed improperly.

TRIPLE-SPOKE SYSTEM

It is conceded that the triple-spoke wire wheel is the strongest for its weight, this having been proved by extreme tests in actual service and having been exem-

plified by two accidents that took place near Buffalo some time ago on the New York Central tracks at about the same point. An automobile equipped with wood wheels was struck by a train traveling at the rate of 40 m.p.h. and was carried about 150 yd., every spoke of the wheels being completely demolished. About 2 weaks later, a second accident of the same kind occurred. This time the train was a Chicago Express, traveling about 60 m.p.h. and the automobile was equipped with wire wheels. Although this accident was more severe than the first one and the car was carried much farther, it was found that two of the wheels were in absolutely perfect condition; a third wheel had only a few broken spokes and could have been used without difficulty; and even the fourth wheel, which received the direct blow from the cowcatcher and was bent considerably out of shape, had more than one-half the spokes still intact.

An interesting feature in connection with their strength is that triple-spoke wire-wheels have been used exclusively for racing purposes, one of the principal reasons, other than the advantage due to quick change, being that they combine strength with lightness and assure safety; furthermore, all the world's records for speed and endurance have been established on cars equipped with wire wheels.

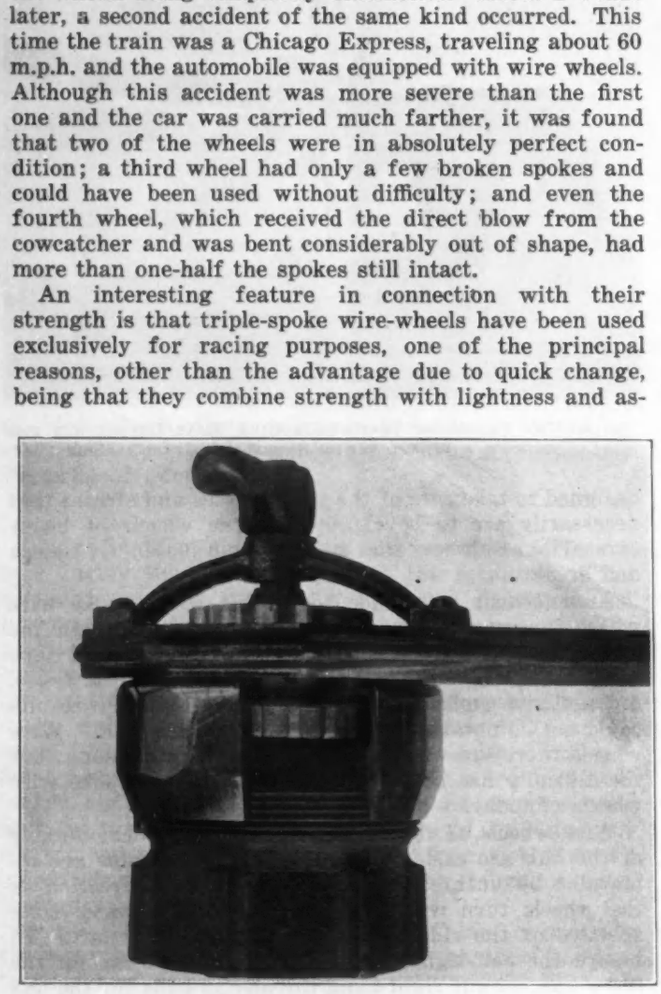

FIG. 5—A POSITIVE LOCKING HUB-CAP CONSISTING OF TWO PRINCIPAL MEMBERS

MILEAGE, TIRE CHANGES AND GET-AWAY

There is no question that greater tire mileage is obtainable from a wire-wheel-equipped car, on account of the resiliency of the wheel, which assists the tire in absorbing road shocks; the metal spokes also radiate the heat generated by the friction of the tires on the road. That can easily be proved, for on a hot day after motoring, say, 50 or more miles, you will find that the tires are hardly warmer than the temperature of the air, whereas with wood wheels, as the spokes are non-conductors of heat, the tires are so hot they cannot be touched; and this heat certainly has a detrimental effect on the life of the rubber. Tests have proved that wire wheels effect a saving in tires of from 25 to 40 per cent.

Quick tire-change is very important as, generally, this is necessary at a most inopportune moment and may interfere with an appointment or with catching a train. The ease with which a tire-change is made is one of the outstanding features of a wire wheel demountable at the hub. All world's records in this respect have been made with wire wheels. At the Indianapolis races, on Decoration Day, 1922, Jimmy Murphy changed all four wheels in the remarkable time of 2 min. Later in the race, as a precaution against tire trouble, he changed his two right-side wheels in 8 sec., establishing a world's record.

It is conceded that a car equipped with wire wheels has a quicker get-away on account of the reduction of peripheral weight of the wheels. The weight of a wire wheel is at the hub, not at the rim, which makes the amount of material that is necessary to set in motion less and, therefore, makes it easier to start and stop the car.

With wire wheels, the weight of the car is hung or suspended; whereas, with wood wheels, it rests on one or two spokes that are in direct contact with the ground. This has particular significance when a wheel strikes against a curb, as one or two spokes may be broken in a wire wheel and the wheel still be in a serviceable condition, while other types would be injured beyond the possibility of use for continuing a trip.

Triple-spoke lacing forms a symmetrical wheel and comprises three distinct sets of spokes, the first extending from the outer end of the hub to the rim; the second, from the inner end of the hub at considerable inclination in the opposite direction to the first set and to the outer half of the rim to pull the rim inward and to counterbalance the pull of the first set; the third, from the inner end of the hub to the inner half of the rim so as to make the wheel rigid. The second and third sets do the driving and the braking, while the first set resists lateral strains from the outside. Any tendency of the rim to tilt in any direction whatsoever will be resisted by certain spokes acting longitudinally in the direction of their greatest strength.

DRIVING PARTS

The earliest types of wire wheels were driven by six or more studs mounted in a hub flange, which corresponded to an equal number of holes in the hub shell and allowed the demounting of the wheel. Several designs of hub shell were made, the type now largely in use having the thickness of the hub-shell metal, plus bosses, pressed up when punching holes for drive studs.

An improvement in the method of driving has been brought out and thoroughly tested and is now in use in wheels of the latest type. This drive, known as a corrugated taper drive, consists of a driving flange on the hub with 18 corrugations on a 20-deg. taper. Corresponding to the taper on the hub flange is a taper on the hub-cap. When this has been screwed into place, it draws the wheel up on the driving flange and seats it on the corrugations, thereby wedging the wheel between the two tapered surfaces and eliminating the possibility of wear when the hub-cap is seated properly. The drive in the wheel itself consists of a separate tapered corrugated ring fitting similar corrugations on the driving member. The ring is a steel stamping pressed into the hub shell, which is crimped or pressed over the driving ring to hold it in place, the spokes being laced through both the inner driving-ring and the outer hub-shell.

It is interesting to note that the corrugated taper surfaces on the hub driving-flange are machined to a

(*Concluded on p.* 233)

A Critical Study of Modern Automotive-Vehicle Steering-Systems

By HERBERT CHASE[1]

ANNUAL MEETING PAPER *Illustrated with* DRAWINGS

IN this paper the matter of locating steering drag-links received considerable attention and this question was also dwelt upon by several of the speakers participating in the discussion following its presentation. For that reason the following contribution by A. W. Werner, chief engineer, Parker Motor Truck Co., Milwaukee, is thought to be of value to engineers who wish to approach the theoretically perfect location of the drag-link. Inasmuch as it is so closely related to Mr. Chase's paper, it has been deemed advisable to print the contribution, which appears below substantially in full, as a contributed discussion of the paper rather than as a separate article. A brief abstract of the paper precedes the discussion together with a reference to the issue of THE JOURNAL in which the paper and the discussion following its presentation were published so that members who desire to refer to the complete text and the illustrations published in connection therewith can do so with a minimum of effort.

ABSTRACT

STATING that automotive literature presents surprisingly little helpful information concerning the faults of the steering-systems used on automotive vehicles and that, in spite of the fact that so many of the faults are self-evident, they frequently are overlooked in actual practice, the author includes with the presentation of his own investigations summaries of the views expressed by numerous well qualified automotive engineers and discusses these steering-gear faults in some detail.

Beginning with the subject of safety, consideration is given successively to the causes of hard steering, the angular position of knuckle-pivots, knuckle-pivot location, the foregather or toe-in of wheels, castering or trailing effect, wheel-wabble, drag-link location, irreversibility, steering-gear type comparisons, tie-rods and tie-rod arms. Numerous drawings illustrative of present-day practice are presented and commented upon, reference being made also to other articles, printed previously, that are pertinent.—[Published in the April, 1923, issue of THE JOURNAL.]

THE DISCUSSION

A. W. WERNER:—In introducing a new method of layout we shall consider the location of the drag-link, since this member is the point of interest and if incorrectly placed will cause as much trouble as any other item in the entire system. Contrary to the universally accepted rule that the position of the drag-link should be such that its center line will intersect the center of the front spring eye, it is a scientific fact that the location of the drag-link depends entirely upon the characteristics of the front-spring design.

Before making a new layout the position of the steering-gear must be assumed and the design of the front spring must also be complete. Next consider the caster of the front axle. This should be made so that the angle from the vertical is the same as the angle of the spindle from the horizontal. On the majority of axles this amounts to from 1¾ to 2 deg. In the layout the spring is always shown in the loaded position.

The next step is to analyze the characteristics of the front spring to determine the exact location of the center of the ball of the steering-arm ball-stud attached to the axle under various positions of the spring. First, it is necessary to determine length l, Fig. 34, when the spring is in its normal rated load position. This length is found by the following formula:

$$1/2L = \sqrt{[(1/2c)^2 + (4/3h)^2]} \qquad (1)$$

where

c = Rated chord length
h = Height from center of the eyes to the top of the spring
L = Length from center to center of the eyes on the arc

FIG. 34—DIAGRAM ILLUSTRATING THE METHOD OF DETERMINING THE APPROXIMATE DEVELOPED LENGTH OF THE FRONT SPRING

From this we can proceed to lay out different positions of the spring, preferably five, two above and two below the normal position, by finding the length c for a predetermined height h. The two positions above and two below the normal position are best considered in steps 1 1-8 in. apart.

To find the length of c for any selected height h, we solve the equation

$$1/2c = \sqrt{[(1/2L^2 - (4/3h)^2]} \qquad (2)$$

Laying out these lengths indicating point o, together with their respective heights, in their natural shackled positions, it will be seen that they follow very closely a true curve, the radius of which is determined by equation (3)

$$R = [(1/2c)^2 + h_1^2]/2h_1 \qquad (3)$$

where

c = Chord length
h_1 = Height from chord line to top of the arc

These positions should appear as shown in Fig. 35.

Intersecting points d-e with the radius at the point a results in determining the exact fulcrum-point o of the spring. Knowing this position, it is necessary to consider only the distance relation x of the center of the ball on the steering-arm ball-stud and point o on the spring, and move the point f to point q a like distance so that it will represent the true fulcrum-point of the ball-stud center as shown in Fig. 36. With the spring in its

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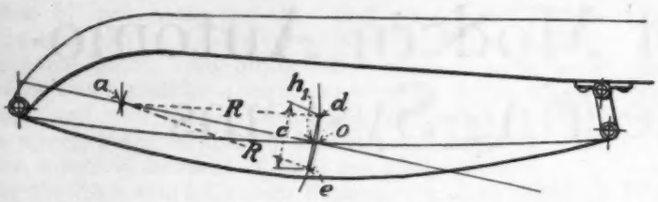

FIG. 35—LOCATING THE CENTER OF THE ARC THAT APPROXIMATES THE LINE OF TRAVEL OF THE STEERING-KNUCKLE ARM END

normal position extend a center line from the point q through the ball-stud center and let it intersect the center of the steering-gear-arm center-line at y.

This concludes the amount of work necessary to determine the correct position of the drag-link in the layout of the steering system. The length of the steering-gear arm can be made in accordance with the designer's wants, with relation to gear-ratio, and the like, but the ball-stud center must be at point y to secure the desired results.

It can be clearly seen that with such a method of layout the arcs of the front axle and of the drag-link are tangent at the point where the *position is most frequent* and that any deviation from this point, regardless of direction, is only slight. In all cases the distance traveled by the point in question results in a very slight tendency to lengthen the centers of the drag-link, which is allowable, since the position of the springs back of the sockets is favorable to this condition.

The condition is improved somewhat by an increase of the distance between the centers of the link. A longer link will remain tangent to the axle arc over a greater distance than will a short one. It is also apparent that no "push" or shortening of the drag-link centers that would tend to deliver a shock to the steering-gear because of the lack of springiness of the link in this direction is introduced.

It would certainly be amiss if we should overlook at this point the usefulness of the method described herein as applied to the brake connections. The entire method, including the consideration of the characteristics of the rear spring design, is applicable to the brake connections that are attached directly to the rear axle of a vehicle. It might be said that in a design employing the Hotchkiss drive this system is almost indispensable, in that we are able to determine the exact fulcrum-point of the axle, also of the eyes of the brake pull-rod levers. To be able to obtain brake connections that do not have a tendency to loosen or tighten the brakes when the axle changes its position means that we are assured of a constant and reliable braking system.

Similar to the consideration given to the drag-link, it is necessary first to lay out several different positions of the spring above and below its normal position, preferably three of each in the case of the rear spring, by the use of formulas (1) and (2). After plotting the point o, which represents a point on the top surface of the spring at its center line, we can again use formula

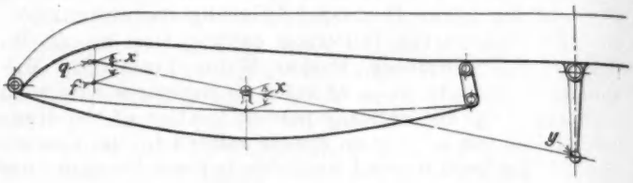

FIG. 36—METHOD OF LOCATING THE END OF THE STEERING-GEAR ARM TO MINIMIZE WHEEL-WABBLE

(3) for obtaining the fulcrum-point. The distance relation between point o and the eye of the brake lever should then be laid out with the same distance relation from the fulcrum-point. This, then, represents the true point of the radius of the eye of the brake lever and the distance between the eye and the fulcrum-point automatically represents the length of the brake pull-rod.

It will be noticed that in a layout of this kind the pull-rod is very much shorter than is usual in vehicles employing the Hotchkiss drive. Nevertheless the layout is absolutely correct and if put to a test will be found to work perfectly. It has been my experience that with this system of brake layout it is unnecessary to employ equalizers. This is due to the fact that regardless of whether one wheel is raised or lowered the fulcrum-point of the brake connections will remain fixed, and since there is no motion at this point there will be no necessity for providing flexibility.

TO INCREASE SAFETY OF HIGHWAY TRAFFIC

SAFETY on the highway is a matter of national concern. During this last year 14,000 lives have been sacrificed in automobile accidents. There are now registered in the United States 12,000,000 motor vehicles. This year's increase to that number is estimated by manufacturers at 3,000,000. The risk to safety lies in the congestion of 90 per cent of these vehicles upon 10 per cent of our roads. This risk we must minimize. That it is at the present time fraught with an appalling loss of human life is evidenced by the casualties from automotive-vehicle accidents, a loss yearly which is greater than by all other means of transportation combined.

The majority of these accidents of congestion occur under five conditions, all of which road builders may help to eliminate.

(1) Sight distance on curves, both horizontal and vertical, which is insufficient to permit precaution against the other man's reckless driving. Lack of sight distance also increases accidents at intersecting roads and railroad crossings

(2) Insufficient width of pavement, especially in congested districts, which increases the number of cars that turn over on soft shoulders and roll down unprotected slopes. Narrow or single-track bridges are a constant menace. In the design of roads 10 ft. should be allowed as a minimum width for each single line of traffic each way and 9 ft. more for each additional line each way

(3) The inadequate, irregular and improper spacing of danger signs that encourages a general carelessness of their import. Judged by the number of accidents in their vicinity, they are a spur to the recklessness of the joy-rider and a consequent risk to his sober brethren

(4) The tendency of detours under traffic to become almost impassable. On heavy-traveled routes traffic going in different directions should be routed over different detours, or, if detours are inadvisable on account of dangerous or impassable conditions, the road should be built horizontally a half at a time

(4) Railroad grade crossings.—Extract from a committee report to National Highway Traffic Association

Comparative Merits of Steel Disc and Wood Wheels for Automobiles

By J. W. WHITE[1]

BUFFALO SECTION PAPER *Illustrated with* DRAWINGS

DISC wheels are the answer to a demand for something better at a more reasonable price. The art of making wood wheels has been established, the machinery has become standardized and further reduction in cost is improbable; whereas, the cost of suitable wood is steadily advancing and the trend, consequently, is upward. When the wire wheel was first introduced its use was a mark of distinction and to it can be traced the origin of the sport model, but its price cannot be reduced and it cannot compete, therefore, with the disc wheel on a price basis. The development of the disc wheel brought an equal distinctiveness of design and of pleasing appearance, but its progress has been different. The initial expenditure involved in the production of disc wheels is large; but the output also is large, and, as the volume increases, the prices become lower. The difference in the cost of painting is another item in favor of the disc wheel over both its competitors, even when the same number of coats are applied, but if high-bake enamel is used a surprising saving can be effected.

Two objections at first arose because of its demountable features: the first, because special carriers were required when the demountable-at-hub type was used; the second, because the demountable-at-rim type made it necessary to get under the car to adjust the brakes. Local conditions produce differences of opinion, wood and wire wheels being preferred in certain sections during wet periods because of the greater facility of handling the wheels by taking hold of the spokes. One of the most serious objections has been due to the trouble experienced in inflating the tires. Efforts to conform to the standards of other wheels brought complications in the use of the valves, so that it has become evident that, to secure the best results, steel wheels must be built around standards of their own.

It is possible to design a disc wheel with a lateral resiliency greater than that of any other type. This is particularly noticeable in turning corners, as it affords material relief to the tires. The tapering of the disc wheel toward the rim causes it to take a deflection readily at the rim but resists it in an increasing ratio as the deflection increases; it thus withstands impacts such as those against a curb that would cause a wood wheel to crack. Much must yet be done with the design to bring disc wheels into common usage, the features that require special study from a technical standpoint being strength, resiliency, fatigue, weight, noise and appearance. An advantage in weight formerly lay in favor of the wood wheel but this condition no longer exists, the disc wheel weighing slightly less in the 32 x 4 in. and the larger sizes. The difference in the energy consumed in accelerating the wood and the disc wheels has been found to be less than 0.01 per cent, which is less than the loss of energy due to windage in accelerating a non-skid tire as compared with that of a smooth tire under the same conditions. Reverse curves and crimps in the disc not only increase the rigidity but tend to restrict the amplification of sound vibrations. The difficulties attendant upon the securing of steel of sufficient and uniform hardness seem to have found solutions in the heat-treating of the metal before or after drawing, or in the using of carbon-steel drawn hot and hardened in a die afterward. Both involve manufacturing difficulties but give a uniform product, and increased strength and a reduced weight.

VERY few developments in the commercial world are a direct advancement. In most cases, progress is traceable to a demand from the user for something better or for a more reasonable price and therefore, in general, the development or improvement of any article is the manufacturer's answer to the demand. The automotive wheel industry of today offers an excellent example of this truism, particularly with regard to disc wheels. The wood wheel needs no apology for its service past or present. In hot dry climates it is at a disadvantage when compared with metal wheels, but far and wide its operation has been satisfactory, while economically its position in the past has been secure. When the wire wheel was first introduced, its use was a mark of distinction on cars of the higher class and a period of natural competition between it and the wood wheel prevailed. Each is now conceded to have a field of application in which its use is desirable.

The development of the disc wheel brought out an equally distinctive design of pleasing appearance, but the effect was entirely different. The price of disc wheels in the early stages was as high as that of wire wheels and their general use was therefore limited. To these two types of the metal wheel, and to the wire wheel in particular, can be traced the origin of the sport model, the finish and appearance of an automobile wheel being one of the featured points in the construction of the car that attracts the public by its racy lines and pleasing colors. It is generally known that one of the most important elements in the cost of a manufactured article is labor. Little argument is necessary to convince the casual observer that the wire wheel has a relatively high direct labor cost in comparison with that of the wood wheel, and that the disc wheel by the same comparison costs much less, especially the single-disc type.

The equipment of presses and tools involved in the manufacture of disc wheels necessitates a large initial expenditure. Once this investment has been made, however, the output of a plant manufacturing disc wheels is greater for the same investment than one manufacturing wheels of any other type. A metal-stamping plant must have quantity production to compete in price but, when volume has been secured, the parts can be produced with a minimum of direct labor cost. A few companies have been able to secure a fairly satisfactory volume of disc-wheel business in the last year, and this has been immediately reflected in the lower prices of disc wheels; consequently, the demand has grown rapidly, and at present the disc wheel appears to be in popular favor.

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It is evident that the wire wheel fills a definite place in the industry. The question is: How far will the metal wheel replace the wood? In this comparison we are considering only the disc type. If it becomes widely used, it will lose the distinctiveness for which it was first favored, and which the wire wheel still retains. By reason of its low direct labor cost, it can compete with the wood wheel, whereas the price of the wire wheel can not be reduced sufficiently to be considered. This condition already prevails in Europe, because suitable wood is very expensive and is almost unobtainable; hence, the metal wheel is now the predominating type.

In general, it can be considered that the art of making wood wheels has been established, that machinery has become standardized and that any great reduction in cost from a manufacturing standpoint is improbable. On the other hand, the cost of suitable wood for fabrication is gradually advancing; in fact, within the last few years the wood felloe has been superseded by the steel felloe mainly because of the scarcity of wood stock. From the foregoing, it is evident that the trend of cost is downward for the disc wheel and upward for the wood wheel.

The cost of painting is another item that handicaps the wood wheel from a manufacturing standpoint. Sanding and rubbing between coats must necessarily be done by hand, whereas high-bake enamel, which is more durable than paint, can be applied to the steel disc wheel at a cost that is a surprising saving. Even when the steel wheel and the wood wheel are given the same number of coats of paint, the operation is much faster on the smooth steel surface than on wooden spokes.

Five or Four-Wheel Sets?

A very interesting problem is introduced with the disc wheel; that is, whether a five or a four-wheel set will be preferred generally. The wire wheel is naturally a five-wheel type, because a steel shell is essential in the fabrication of the wheel at the hub. This has developed the single nut and quick-detachable feature, because this was the only sure way of mounting the shell on the hub so that backlash would be avoided and the freezing of the shell to the hub would be prevented. Four-wheel equipment has been standard with the wood-wheel industry mainly because it is necessary to assemble the wooden spokes with the hub in place, to prevent movement and to retain the banding pressure incident to their manufacture. The disc wheel is favored because it can be made either way.

The first sets naturally were demountable at the hub, to invite comparison with the wire wheel, and also because the unsprung weight was less than with four-wheel equipment. As disc wheels came into more general production, five-wheel equipment, demountable at the hub, met with some objection from automobile manufacturers, because special carriers were required. Wood wheels were the rule and steel wheels the exception. Confusion resulted on the assembling track because of the necessity of using two different types of carrier. The natural thing, therefore, was to design a disc that would take the wood-wheel rim and hub and allow the use of the same rims and carrier, thereby making the least possible change in the routine of factory production. It appears, however, that the quick-change feature of the demountable-at-hub type is in demand and on the increase. Another objection, which has become evident on disc wheels that are demountable at the rim only, is that it is necessary to get under the car to adjust the brakes; whereas, with wood wheels, adjustment can be made from the outside of the car. This has made it advisable for all steel wheels to be demountable at the hub, even though they are demountable at the rim as well, and this feature is becoming standard.

It would seem that the disc wheel of the future should be demountable at both the rim and the hub; at the rim, to conform with wood-wheel carriers, which are less expensive, and at the hub to allow brake adjustment and quick change. Engineers are about equally divided in their opinions as to the use of four or five-wheel equipment, and it is logical to believe that the general public has similar differences of opinion. It also has developed that certain localities favor one type or the other because of existing conditions. For instance, in wet weather, in localities where adobe soil is prevalent, the change of the rim is preferable to that of the disc because the disc wheel cannot be handled by the spokes as can the wire or wood wheel. On the other hand, the demountable-at-hub type is easier to change mechanically, especially if it is used with a single nut as is the wire wheel. Disc wheels can now be made doubly demountable and as light as the five-wheel type; and this allows the manufacturer to supply four, five or six-wheel equipment, as may be preferred by the customer.

Disc-Wheel-Tire Inflation

One of the most serious objections has been the trouble experienced in inflating the tire. Up to 2 years ago, it was general practice to use a standard air-valve that passed to the rear of the disc, making it necessary to get behind the wheel to inflate it. This was awkward, unsatisfactory and troublesome; consequently, the owner let the tires become soft before paying attention to them and damage to the tire carcass and the cutting down of the life of the tire were the results. This caused all kinds of complications, on account of the complaints of users to the service branches of the tire companies regarding tire mileage, and resulted in a demand that the tire be inflated from the face of the disc. The angle-valve was the answer, and it has been used rather extensively for this purpose with some success. The chief objection to the angle-valve, however, is in the service. All sorts of angle-valves have been placed on the market. Patent extensions, rubber tubes and the like, have been supplied in an effort to overcome the objections, but the problem still exists. The stock carried by the tire companies at their branches and service-stations is equipped with standard valves. As different types of disc wheel have been adopted by various automobile companies, they have requested that the tire manufacturers furnish tires with the type of valve necessary for the type of disc in use by them, as shown in Fig. 1, and that the tire companies stock the various branches with tubes equipped with valves for those types. In a short time the tire companies were swamped with requests of this nature, and it became impossible from a financial standpoint for them to carry the burden of the increased inventory. As the car owner wears out his tires, he naturally buys new ones wherever he can, and takes the valve that comes with it. A number of wheel manufacturers have sought to overcome this objection by designing wheels that could use the standard straight valve now used with wood wheels. At first, it was thought impossible to do this without sacrificing strength and appearance, but good results are now being accomplished.

Disc and Wood-Wheel Comparisons

It will appear from the foregoing that, up to the present, the development of steel disc wheels has followed the

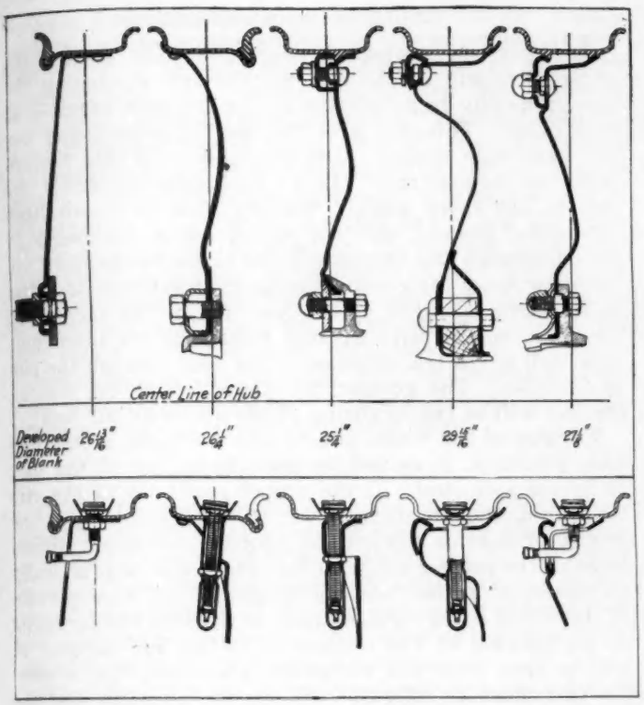


FIG. 1—TYPES OF DISC WHEEL AND THE VALVES USED WITH THEM

path of least resistance and that available standard parts have been used so far as possible. Upon careful analysis, it also appears that this has been responsible for most of the objections that have been directed against disc wheels. As their use increases, and more attention is paid to the fine points of their design, it is becoming more evident that to secure the best appearance, lightest weight, lowest cost and best operation, steel wheels must be built around a standard of their own. The rims that are used for wood wheels have been found too heavy and the locking-devices cumbersome. If disc wheels are substituted for wood wheels, the changes in design that would be warranted would modify axle design. For instance, with a single disc, the axle itself could be shortened by an amount equal to the difference in the widths of the wood wheel and the disc. The hub construction could be changed so that the bearing support in the semi-floating type of axle would be so close to the center of the wheel that it would become an almost universal type, making a substantial reduction in the cost of the axle itself and of the hub. If the four-wheel brake ever comes into general use on passenger cars, the use of steel disc wheels will follow, naturally.

Radially, the wood wheel has no resiliency at all; laterally, it has considerable, but this is restricted greatly by the rigidity of the felloe, the felloe-band and the rim, when they are clamped together as a unit. Any side pressure, therefore, is transmitted through the spokes in the lower half of the wheel in one direction and through the spokes in the upper half in the opposite direction, this movement being resisted by the diameter of the hub flange. In the disc wheel, a load-impact at any particular point causes the deflection of the rim at the point, as illustrated in Fig. 2, and the more the rim is deflected, the more the load is transferred by the rim round the wheel and absorbed. It is possible to design a disc wheel with a lateral resiliency greater than in any other type. This holds true only for the single-disc type or for composite designs that embody the same characteristics. To get extreme lateral resiliency in the disc wheel, the resistance to deflection must build up rapidly, as deflection is caused by impact. This is particularly noticeable in turning corners, as it affords material relief to the tires, the strain being absorbed more in the disc itself and the rim with a substantial reduction in skidding. The more rigid the wheel is laterally, the greater will be the shock that the tire must absorb; consequently, the tire will skid or transfer shock strains to the axle.

Another condition observed in wood wheels is the cracking at the hub that is caused by a sudden impact against a curb or other obstruction. The reason is that the spokes are not tapered toward the rim, because a large diameter is necessary at the rim to provide for a tenon and also to carry the load at the rim. If this were not necessary, the spokes could be tapered and the wheel would be fairly flexible laterally at the rim. Because of this rigidity at the rim and the inability of the spokes to flex as wood naturally does, the impact is sudden and localizes the strain at the weakest point in the spokes, which is also the point of greatest leverage. This condition does not exist in a disc wheel because, by tapering the disc toward the rim, or by securing the same result by the shape of the disc from the hub to the rim, the rim takes a deflection very readily but resists deflection in an increasing ratio as the deflection increases, similarly to the spring action on the car itself. This, together with the toughness of the steel-disc wheel, prevents the wheel from collapsing under the conditions mentioned above. Even though the blow may be sufficient to give it a permanent set, the shock is cushioned to save the axle; and the driver can get home. Much must yet be done with the design of disc wheels to bring them into common usage but, from the standpoint of design, none of the obstacles that have yet been encountered indicates that there is anything which will prevent them from becoming practicable from a cost or an operating standpoint.

ESSENTIAL TECHNICAL FEATURES

The essential features of the disc wheel that require careful study from a technical standpoint are: strength,

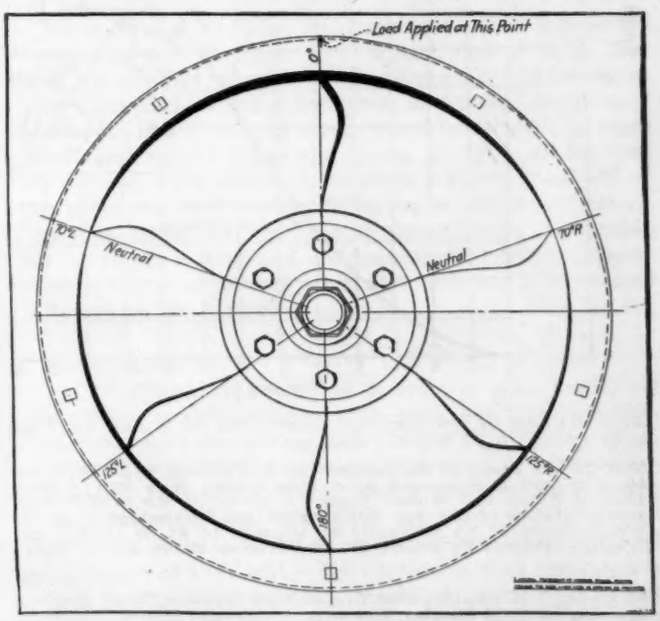


FIG. 2—LATERAL MOVEMENT AT VARIOUS RADIAL POINTS AROUND THE CIRCUMFERENCE OF A DISC WHEEL WHEN THE LOAD IS APPLIED AT THE TOP

resiliency, fatigue, weight, noise and appearance. The first four are all dependent one upon the other.

Strength can be secured by the shape, the thickness, the distribution and the physical characteristics of the metal used, also by the diameter and the design of the hub and the rim parts. Some designers prefer a disc thick at the center and tapering toward the rim to give strength to the hub. This limits the shape considerably because it is difficult to draw steel of tapering section into sheet form; therefore, discs of this type usually are of plain shape with few curves. General opinion favors a disc with curved lines, which, when rightly formed, will give the same results as a disc with tapered section.

In Fig. 1, the drawing at the extreme left shows a typical section of the tapered disc with plain surface; the next view to the right shows a disc that is tapered at the outer portion but is constant in section from the center of the disc to the hub. They illustrate the use of a curved shape and a tapered section to secure the same result. Discs of this type usually are turned after forming to secure the taper. The drawing at the extreme right shows a constant-section disc of the four-wheel type; and the central drawing illustrates a disc of constant section demountable at the hub and the rim with reverse curves to strengthen the disc and a hub grip at an angle to give a greater virtual thickness of metal at this point.

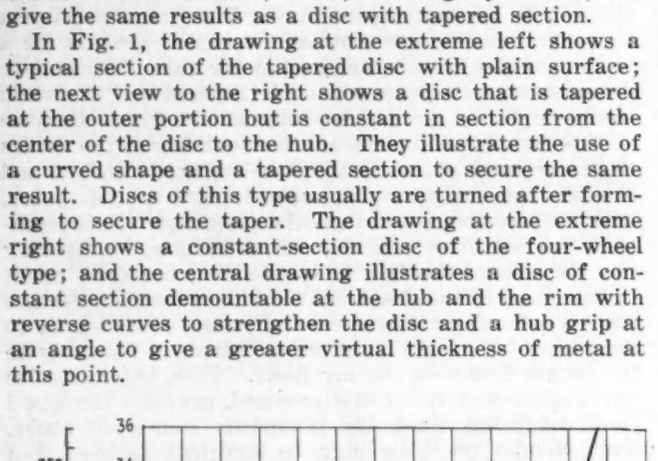


FIG. 3—CURVE OF ACCELERATION LOSSES DUE TO WHEEL AND TIRE WEIGHTS

This Test Is Based on the Acceleration of Different Types of Wheel by a Weight *x* Suspended by a Fine Copper Wire over a Ball-Bearing Pulley and Wound Around a Pulley on the Wheel Shaft with a Radius of 3¼ In. All Results Are Determined from the Weight Required To Accelerate by Gravity, 10 Ft. in 10 Sec., the Relative Weights To Secure the Acceleration Shown on the Curve

	Weight, Lb.
31 x 4-In. Cord Straight-Side Tire with All-Weather Tread	2.95
30 x 3½-In. Cord Clincher Tire with All-Weather Tread	1.19
Demountable-Hub Type Disc Wheel	2.05
Demountable-Hub Type Disc Wheel	2.03
Demountable-Rim Type Disc Wheel	2.08
Wood Wheel with Wood Felloe	2.03

RESILIENCY AND FATIGUE

Resiliency in a wheel is secured by first getting the proper strength at the hub portion and weakening the disc outwardly in proportion to the strength required at each point. This will give the maximum resiliency for any particular design. The desirability of this feature is not appreciated fully. In the first place, the stiffer the disc is, the more quickly will the blow be transmitted throughout the car, with the consequent inconvenience to the passengers and excessive shock to the mechanism. On the other hand, the greater the lateral movement of a disc of the same strength is, the less will be the fatigue at the hub, because with greater movement the more uniform will be the transmission of the load through the rim to the disc. The greater the distortion at the rim is, the less will be the localizing of the stress on the hub.

Fatigue of the wheel usually is manifested at the hub and, generally, is caused by poor designing of the disc or by too soft steel. If the proper resiliency at the rim is secured, and the strength of the wheel builds-up in the proper proportion toward the hub, the movement diminishes in the reverse ratio, so that there will be practically no movement at the clamping flange. If the outer portion of the wheel is too rigid, fatigue at the hub will certainly occur, because of the movement at the hub flange. It will be seen from the foregoing, therefore, that a compromise must be effected between the strength and the resiliency to secure proper results; and the more carefully and correctly this is done, the more weight can be saved. It is apparent also that the higher the elastic-limit of the metal is, the greater the resiliency will be, the strength remaining constant.

Much has been said as regards the extra weight of the disc wheel over that of the wood wheel, but these conditions no longer exist. A well-designed disc wheel weighs slightly less than a wood wheel in the 32 x 4-in. size; in the larger sizes, the saving increases rapidly in favor of the disc wheel. In the 30 x 3½-in. size, there is still a slight saving in weight in favor of the wood wheel.

ENERGY FOR ACCELERATION

Considerable comment has been made as to the energy consumed in accelerating a steel wheel on account of its being heavier at the rim. I have made a number of careful tests as shown in Fig. 3, and find that the difference between the energy required to accelerate the heaviest disc wheel to a speed of 15 m.p.h. and that required for the wood wheel averages less than 0.01 per cent, assuming a 10-sec. period of acceleration in high gear, which is practically impossible to secure.

It has been found that the loss of energy due to windage in accelerating a non-skid tire as compared with that of a smooth tire under the same conditions is greater than the difference in the wheels themselves.

NOISE

Noise in the wheel is of two kinds: (*a*) the reflected noise and vibration from chassis parts and (*b*) amplification of this noise because of the shape of the disc being like that of a bell or a sounding board. Broadly speaking, tapered discs generally accentuate the noise, because the discs are sensitive to vibrations of low periodicity. Reverse curves and crimps in the disc tend to break up the free motion of the disc and, therefore, not only increase rigidity, but restrict the amplification of the vibrations. A disc properly designed should be dead, practically, so far as vibration and sound are concerned and, accordingly, the disc wheel should be quieter than others,

because it blankets the noises that come from the chassis, at least so far as their effect on the passenger is concerned. It is well known that chassis noises are more apparent when the running-boards have been removed.

So far as appearance is concerned, "the least said the soonest mended." One thing, however, that can be said is that large plain surfaces do not set the car off; and the general inclination of the purchaser is toward a disc in which there is a certain natural grace and strength. There is probably no wheel on the market today that lends itself to various color schemes as does the disc, because its smooth surface gives a more intimate relation between the wheels and the trimming of the car. The fact that a car has disc wheels is one of the noticeable impressions that the observer first receives and, therefore, will always merit careful attention from the standpoints of color value and decorative effect.

Steel for Disc Wheels

One of the great problems in the manufacture of disc wheels is the securing of proper steel. The average disc is made of S. A. E. 1020 steel, either hot or cold-rolled; in either case they should be full-pickled and the surface should be as smooth as possible, because, if objectionable pits and tears are present, they must either be polished out or filled during the painting operation.

When the discs are to be enameled it is usual to call for full-pickled full-cold-rolled stock. In most cases this surface will give a good enamel finish without further preparation. It is necessary, of course, that care should be used in handling discs of this finish in large production. The polishing equipment and space saved is well worth extra cost of full-finish material. When discs are to be painted it has been usual to use hot-rolled stock, because small defects can be covered-up in filling coats, but the full-finish material is preferable on account of the labor saved in the rubbing and filler coats that are objectionable because they crack in service. The real problem, however, is to secure steel of sufficient and uniform hardness. It is difficult to control the temperature of the billet during the rolling operation, and the hardness varies greatly unless the sheets are reannealed. The hardness of a sheet and the carbon-content should be as high as can be drawn in the press without injury to the metal and, therefore, the more difficult the shape is to draw, the softer is the metal that is used. In fact, the secret of making disc wheels is to make a design that will not draw the metal more than is absolutely necessary; in other words, to make the shape so that the punch will lay the metal into the die, instead of drawing it, because a certain amount of thinning occurs in the average disc, usually at the hub flange, which is the fatigue-point in operation.

A Brinell hardness of 130 to 145 is satisfactory for average purposes. We should like to go much higher but, at present, this does not appear practicable on account of the wide range of hardness that the mills demand; that is, 50 points. A disc of 100 Brinell hardness under test has shown fatigue about three times as quickly as a disc of 145 Brinell, although the grain structure of the harder disc may not be as good. Fatigue usually occurs at the hub, and a harder metal makes a stiffer disc with less lateral movement under the same load; whereas, the softer disc may show better structure and ductility, but moves so much more that fatigue occurs earlier. It is manifestly impossible to manufacture discs with these wide variations in hardness, successfully.

The solutions that appear possible are to heat-treat the metal before or after drawing, or to use high-carbon steel drawn hot and hardened in a die afterward. Both these alternatives involve numerous manufacturing difficulties. On the other hand, either of these processes will give a uniform product, an increased strength and a reduced weight. The future of the disc wheel appears to depend on the commercial development of some process similar to those outlined above.

Finish

Few people seem to realize the relation between the finished surface of the metal and the life of the paint. On an automobile body we apply from 5 to 15 coats of rough-stuff and paint to build up a good surface, and the same method has been followed in finishing disc wheels. This is absolutely contrary to what should be done. A disc wheel is subject to severe vibrations and deflections in service. The heat from the brake-drum is sometimes transmitted to the rear wheels, consequently the same conditions that apply to the painting of the body do not apply to the wheels; in fact, the ultimate disc wheel will furnish the same relative resiliency to the movement of the car laterally that the springs do vertically.

Fillers and rough-stuff are notoriously short in oil, whereas the varnishes are long in oil. It is apparent, therefore, that a filler or a primer will not hold to the disc as well as paints and varnishes long in oil. The smoother the disc is, the less of the primer or the filler that will be necessary; in fact, the first coat that is applied to the disc should be an oil coat to afford a surface for the color coat. The number of coats should be reduced to at least four, namely: (*a*) an oil coat baked on, (*b*) a color primer long in oil, (*c*) a color varnish and (*d*) a finishing-varnish. I am assuming, of course, that the necessary rubbing will take place between the coats and that oil-rubbing and sanding will be used in place of water. I should like to see the day when we can dispense with the primer coat entirely and use nothing but oil and varnish. It is apparent that enameling is the ideal finish for disc wheels but, on account of the decorative value of color, paint will commonly be used as well, particularly for sport models.

What the future holds for the disc wheel is impossible to forecast at this time. It is a fact, nevertheless, that with the scarcity of good wood, automobile builders have been compelled to find substitutes, and today even closed bodies are being made of steel. Steel lends itself to more economical manufacture and larger quantity production. We believe, therefore, that wheels will follow the trend of the times and will eventually be made entirely of metal. The disc wheel, by design and construction, is suitable for large production and low manufacturing-cost; therefore, it should assume a prominent position in the wheel industry of the future.

THE DISCUSSION

H. T. Myers:—Looking at it from a sales angle, we are confronted occasionally with questions from prospective customers concerning the virtues of different types of disc wheel and the problem of trying to explain the difference between a convex and a concave wheel as to cleanliness, looks and durability, the advantage of a convex over a concave wheel as to its being more soundproof and things of that sort. My opinion is that the concave wheel is the better looking wheel but, some time ago, a representative of one of the companies maintained that a convex wheel was cleaner and stronger and that it would be the ultimate wheel; that the concave wheel was noisy

and had a tendency to collect dust. To prove his contentions, he challenged us to drive concave wheels over dusty roads, and also made tests for wheel rumble.

J. W. WHITE:—Differences of opinion make a horse-race. I think, however, that Mr. Myers' statements can be questioned. Speaking of the wheel to which he refers, I think there is no doubt about its being an easy wheel to keep clean, although the gutter between the disc and the outer edge of the rim collects dust, dirt and water. I assume that when Mr. Myers says that an extreme design will collect dust, he refers to a wheel that is dished deeply. So far as noise is concerned, I should like to take issue with Mr. Myers. If you put crimps in the surface of a disc wheel you naturally will reduce the noise. A tapered section represents the section of a bell more nearly.

E. T. MATHEWSON:—How does the wire wheel compare with the disc wheel and the wood wheel as to flexibility?

W. W. DAVISON:—The lateral resistance of a wire wheel is much greater than that of either a wood or a disc wheel on account of the number of spokes and their high lacing tension. A wire wheel is three to four times as strong as either a wood or a disc wheel under strains of this kind.

MR. WHITE:—I can amplify Mr. Davison's statement in this way: A wire wheel is assembled under tension; you cannot have lateral movement in a wire wheel until the load applied exceeds the lacing tension; you must overcome the tension of the wheel before you can get any movement.

A MEMBER:—Will the corrugated drive become loose under ordinary conditions?

MR. WHITE:—We ran the corrugated drive for 1,000,000 torque oscillations; with a 54,000-lb-in. torque on a 30 x 3½-in. disc. The wheel on an average car of this size will deliver a torque of about 5000 to 6000 lb-in. to the road before losing traction; so, this load represents 10 times the maximum driving effort. At the end of 5000 oscillations, it had a 0.005-in. movement and at the end of 1,000,000 oscillations did not appear to have any.

F. GORDON REID:—I think Mr. White has brought out the fact that, in general, the merits of disc wheels are argued without knowledge. The difference in the weight and in where the weight is placed on the wheel certainly has an effect on the acceleration of the car, but the fact that the difference in acceleration between a rib tread and a non-skid tire was more than the difference between the lightest and the heaviest wheel tested is very interesting. To my mind, it will develop eventually that every automobile disc-wheel will be a glorified brake-drum, because tire sections are becoming larger to make riding easier. The rim will go on the brake-drum and the wheel will have an 8-in. tire. We have found that too much movement causes crystallization; so, we tried to prevent movement. Practically every automobile wheel that goes out of commission does so because it skids. The wheel that takes the least permanent set after a skid, it seems to me, is the best wheel.

E. S. INGHAM:—I am not an engineer; I am a serviceman. We have made both kinds of disc wheel, the convex and the concave. The blow that a convex disc-wheel gets puts the steel under tension. When a concave disc-wheel gets a sufficiently hard blow, the wheel will buckle and turn inside out. Our service-station repairs a large number of wheels other than those of our own make, and we know this to be a fact. Our wheels do not turn inside out; that is one point in favor of the convex wheel. The disc always is under pressure and the side blow must overcome that pressure.

MR. WHITE:—Mr. Ingham is correct in his statement that the convex wheel does take a shock well. You will notice in our design, however, that we have one concave shape changing to a convex at the hub. The reason we use two curves is to take shocks in both directions.

MR. REID:—Why are the nuts on the right side of the wheel represented by Mr. Ingham made with a left-hand thread and vice versa.

MR. INGHAM:—The principle is similar to that used with the hub-cap, but different. It is for the purpose of keeping the nuts tight. In our design, we have a different action. The disc is mounted on the hub and touches the hub only at the outer edge. The weight of the disc is carried on the nuts. The steel, being channeled, has naturally a certain amount of give. It is a fact that there would be a tendency to loosen the nuts if they were reversed. The flexing action on the nuts will keep them tight.

Discussion of Papers at the Semi-Annual Meeting

THE discussion of the papers presented at the recent Semi-Annual Meeting of the Society included written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, are included in the discussions. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with a minimum of effort. The paper by James J. Shanley on Automobile Head-Lamp Regulation is printed elsewhere in this issue.

SHOEING A CAR WITH LOW-PRESSURE AIR

BY J. E. HALE

THE author describes the results of a deliberate attempt to make motor vehicles ride on air that is at a low pressure, through the usage of an air-cushion tire having greater carcass flexibility than is usual and by enlarging the size of the tire section so as to provide a greater area of contact between the tire and the pavement. The goal tried for was to increase the area of contact sufficiently so that air pressures ranging from 20 to 35 lb. per sq. in. could be employed in actual practice.

Fundamental conditions are considered first, followed by statements as to what advantages the air-cushion tires containing air at low pressure give to a car. The effects on car operation are presented at some length, inclusive of considerations regarding car speed, steering ability, front-wheel shimmy, traction, braking control, blow-outs, side-sway and other factors of influence.

Durability and tire cost are treated in some detail, specific applications of air-cushion tires to automobiles are considered and a discussion of their desirability is invited. In conclusion, recommendations are made for a new tire-size nomenclature, in regard to oversizing and to tire-deflection limitation; and specific tire-size recommendations for air-cushion tires on stated makes of car are advocated in the Appendix and tabulated. Numerous illustrations and diagrams accompany the paper.—[Printed in the July, 1923, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN T. J. LITLE, JR.:—We have asked the members to write their questions on the cards that were distributed rather than to state their questions verbally, for two reasons. First, questions will occur to the members as the paper is being read and, if these are jotted down on a card, they will be better questions than would be put extemporaneously from the floor. Second, many of us have the habit of getting up to ask a question and then continuing with a sort of lecture of our own that becomes very much involved and takes too much time. In the Detroit Section meetings, we have had as many as 65 questions asked and answered by the author of the paper in a single evening. Not more than from 12 to 15 questions can be asked from the floor and answered by the author within that time. Incidentally, this method is a sample demonstration that can be followed out in the Section meetings throughout the Country. I will now read the questions and Mr. Hale will answer them, one at a time. I will not read the name of the questioner to avoid possible embarrassment to him.

QUESTION:—Is it possible that a 7-in. tire on a heavy car would, upon rounding a sharp curve at high speed, be rolled over to such an extent that its side-walls would make contact with the road?

JAMES E. HALE:—Not if there were sufficient air-pressure in the tire.

QUESTION:—Why call them "air-cushion tires" when we already have so much confusion in defining a cushion tire? Why not call them "super-pneumatic" tires?

MR. HALE:—The Nomenclature Division of the Society might do some good work on that. I think a certain company might object to that particular term.

QUESTION:—Do you think it possible to decrease the running clearance over the front and the rear axles with the use of large tires? What is the cost in comparison with that of ordinary pneumatic tires? What is the effect of scraping the air-cushion tire side-walls on the curbing?

MR. HALE:—I think the road clearance will have to be figured substantially the same as for the high-pressure pneumatic tires. The comparative cost is not available at present because we have not got into volume production, but I can state that the tires will not cost enough more to make any sales resistance against putting them on the market. The side-walls seem to resist curb-scraping very much better than do those of the high-pressure pneumatic tires.

QUESTION:—Have any tests been made to determine the running temperature of the air-cushion tires?

MR. HALE:—No, but the temperatures will be very low because the carcass has no body to hold the heat.

QUESTION:—What is the effect on the air-cushion tires when running in deep, narrow ruts in clay roads?

MR. HALE:—The effect is the same as when a 5-in. tire runs in a rut that is made by cars having smaller tires.

QUESTION:—How long does the tire inflation last?

MR. HALE:—The tube seems to hold the air considerably better than does the tube of the high-pressure tire, because of the lower air-pressure. I cannot say how much longer it holds the pressure.

CHAIRMAN LITLE:—Would the leakage naturally be more rapid at the higher pressure?

MR. HALE:—Yes.

QUESTION:—With the improved performance of the air-cushion tires, would it be possible to use plain tread, or grooved, tires instead of the non-skid types?

MR. HALE:—We are trying grooved treads now and their success looks promising; we have made these tires with nine ribs. However, we cannot say whether they will be entirely satisfactory for replacing the non-skid treads.

QUESTION:—What is the value of the air-cushion tires for bus work?

MR. HALE:—They are being tried, but we have not proceeded far enough with our tests to have any definite information.

QUESTION:—How does the air-cushion tire compare with the high-pressure tire regarding resistance to puncture?

MR. HALE:—A car in our test fleet had one puncture in 7000 miles; on taxicab work, one puncture in 3700 miles.

QUESTION:—Were the taxicab economy-tests run under the same weather conditions, so that the engines were operating under comparable temperature conditions?

MR. HALE:—The figures given are for cabs running side-by-side in April. The high-pressure tires did not run one month and the air-cushion tires the next, but during the same testing period.

QUESTION:—What is the intended shape of the felloe for these tires? Is it the intention to use more than one felloe for the different size tire-bases in line with the recent standardization made by some of the tire companies for truck sizes? This refers to the rim-mounting feature.

MR. HALE:—No work has been done on that thus far.

QUESTION:—How many air-cushion tires have been run to destruction and what is the average mileage?

MR. HALE:—I do not have that information with me. If the person who wrote the question will write me, I will be glad to give him a suitable answer.

QUESTION:—When using air-cushion tires, why are snubbers necessary, the term "snubbers" meaning any good shock-absorber to check the rebound of the springs?

MR. HALE:—Without snubbers, the rebound inherent in the springs is multiplied by the soft cushioning of the air; it simply produces an excessive rebound in going over long ups-and-downs in the road.

QUESTION:—What is the effect of deep ruts on the thin side-walls?

MR. HALE:—It is about the same as on the high-pressure pneumatic tires. We have made no extensive tests on that, however.

CHAIRMAN LITLE:—I have been driving a car for many thousands of miles on air-cushion tires and my practice is to straddle the ruts in many cases. I find that I can go over the rough, broken-up ground more easily with the large tire than with the small size. Ordinarily, I do not ride in the ruts nearly as much as I would with an ordinary tire. Does Mr. Hale agree with that?

MR. HALE:—Yes.

QUESTION:—What is the effect on the road due to air-cushion tires throwing stones, gravel and dust by suction?

MR. HALE:—I do not know.

CHAIRMAN LITLE:—Did your ultra-rapid motion-picture show anything in that connection?

MR. HALE:—I think not.

QUESTION:—What will be the effect on tires, wheels and rims, if the average car-user neglects to maintain the proper air-pressures?

MR. HALE:—I do not know.

QUESTION:—What is the relative volume and the relative weight of air in high-pressure and in low-pressure tires, when applied to the same car?

MR. HALE:—We do not measure the volume and the weight of the air because I think they do not mean anything. However, I will be glad to procure those figures for whomever is interested.

QUESTION:—Is hardness of steering when about to park a car partly offset by the ability of the wheels to mount the curb?

MR. HALE:—It is expedient to climb the curb if it helps the car to get into postion, that is all.

CHAIRMAN LITLE:—I do that about half the time.

QUESTION:—What are the reasons for saying, for instance, a 7.30 instead of a 34 x 7-in. tire?

MR. HALE:—What is a 34 x 7-in. tire? I know of no tire that has a measurement of 34 in. and none that has a measurement of 7 in.; so why call it 34 x 7? My thought is that the logical thing to do is to name the tires by an actual measurement that we find on the tire. When I say a 7.30 tire, calipers will show that the sections actually measure 7.30 in. The reason I do not use the standing diameter is that it seems unnecessary; there is only one standing diameter for a 7.30 tire. So, why not have a short cut?

CHAIRMAN LITLE:—Something was said about hard steering. It may be up to the engineer or to the gear manufacturer to make a steering-gear that will steer more easily and overcome the slight objection that some one might have to these air-cushion tires.

F. F. CHANDLER:—The company I represent has felt for some time that the subject of easy steering has not been studied carefully enough. We are now engaging in an engineering study of the subject. Also, we have produced a gear that, in our opinion, will do much toward accomplishing the satisfactory handling of the air-cushion tires. The whole subject of steering is one that is mixed up with the air-cushion-tire business, with the front-wheel-axle design, the drag-link connections, the kind of bearings in the kingpins and many other matters. It is a joint subject that should be studied by all. We are preparing to work out the better steering of automobiles, either individually or, more properly, in conjunction with others.

CHARLES L. NEDOMA:—Our experience is not as lengthy as that of the company Mr. Hale represents, which has been using their air-cushion tires for a long time. Their car rides more comfortably; however, the liability to puncture appears to be greater. We have found that a little tack that usually would not damage the ordinary tire blows-out the air-cushion tire. We had about six punctures in 8500 miles. The steering, I would say, is more difficult than with the ordinary tire, and the car lacks stability at high speeds.

CHAIRMAN LITLE:—Do you believe that some work might be done on the steering-gear to improve these conditions?

MR. NEDOMA:—Yes.

ERNEST WOOLER:—To emphasize the statements in Mr. Hale's paper about the skidding possibilities, it was raining when I left Cleveland to drive here, using air-cushion tires. A friend of mine who used ordinary tires and usually is a fast driver could not keep up with me. He noticed the chuck-holes during the entire trip and I did not know there were any. Steering changes already have been made on the car I am driving, so that the car now steers as easily as any I ever drove. The dust-raising properties of the air-cushion tires are a great disadvantage and so is the stone-throwing on a gravel road. I know of no other disadvantages as yet.

PAUL W. LITCHFIELD[1]:—We have had considerable experience in the past 3 or 4 years with tires of large cross-section and lower air pressures. It is well known, I think, by everybody in the automobile and in the tire business that there has not been the sufficient cushioning by the use of pneumatic tires that there should have been. It has always been a question with the tire manufacturers of trying to get the automobile builders to put on tires of larger air-volume, so that they could use lower air-pressures. The 10-per cent oversize in tires was largely an effort to get a larger tire on the existing rims, a tire with a larger volume that required less pressure, because it was realized that there would be increased comfort and not necessarily an increased cost per mile. It is a question, I think, of how far it is necessary to go in this direction. The time has arrived in the development of cord tires, I believe, when tires of larger cross-section and lower air-pressures can be introduced with very little increase in the original cost of the tire equipment and probably at a decreased cost per mile. The question is not whether it is a good thing, but how far to go and where to standardize. In the proposed schedule the weights are kept down to a certain extent by using narrower rims than the present standard. We found in several instances in the past that we had to widen the rims to get the proper rim stability to prevent shimmying and side-sway. We originally put a 3½ and a 4-in. tire on the same size of rim, and we had to make a wider rim for the 4-in. tire. We had to do the same thing with the 4½ and 5-in. tires, reducing the 5-in. rim when it came to sizes over 5 in. to secure rim stability.

For good equipment, we feel that it is necessary to use a wider cross-section of rim than that recommended by Mr. Hale's paper, which does not mean much increase in the weight, necessarily. At present, we have 4-in. rims; for instance, when using a 3½-in. tire, the 4-in. rim could be lightened. The use of tires of larger diameter necessitates the use of smaller wheels; instead of having 23, 24 and 25-in. wheels we can use wheels of 20-in. diameter. Therefore, the section in the rim can be made lighter and we still have the same stiffness. Thus, weight can be saved in the design of the rims without getting the rims too narrow to give the proper stability. Shimmying and the difficulty in steering are increased by making the rim too narrow, because the tire balloons over the rim to a greater extent and we have, in some measure, the troubles that we have in steering a tire that is insufficiently inflated; whereas, if the rim were made wider, we would get better stability to make it steer more easily and also to be able to drive with much greater safety at a higher speed.

Some of the exhibition cars that are here have 7-in. tires on 4½-in. rims. We have a car here that has 5-in. rims and 6-in. tires, which we believe to be a better equipment. To get the excess of air volume and still lower pressures and to keep the cost down means making a thinner carcass. We must have a certain amount of body in that carcass to prevent punctures and bruises and the picking-up of glass. While thickness is not necessary to hold the pressure, we must have a certain thickness there to prevent undue cutting and destroying of the tire by obstructions on rough roads. The tires on this car were inflated to a pressure of about 26 or 28 lb. per sq. in. for a 6-in. tire, which is sufficient for a car of this particular type. We do not feel that it is necessary to go to a 7-in. tire and, to keep down the cost, get a still thinner tire and put it on a narrower rim that does not give the proper stability.

In regard to not providing for over-sizing, Mr. Hale states that he thinks the time has gone by when the car builder will not put on a large enough tire. The very fact that these balloon tires are necessary at all shows that they are not putting on large enough tires because, if they did, they already would have reached that stage before this. We think that there always will be, in competition at least, a tendency to put on as small a tire as will be guaranteed under ordinary circumstances to give satisfactory results. There always will be times, with different sizes and types of bodies and with poor road conditions, where cars must be equipped with a larger-size tire than constitutes the original equipment. We think that the rims on a car should be such that, in case a sedan body is put on or the car is used in rough country where the roads are not good, the owner will have a rim that will take a larger tire and still give him economical wear.

Mr. Hale speaks of a 7.30 size of the tire instead of a 34 x 7 in. So long as there are wheels of different diameters it will be necessary to put in an over-all diameter to distinguish one from the other. To say "7-in. tire" is supposed to mean 7 in. but, in tire design, it varies more or less. We will have to get a nomenclature for the sizes similar to that used now.

S. P. THATCHER[2]:—The balloon-tire problem is another very fine illustration of the fact that a pneumatic tire is a compromise of many desirable qualities. We can increase any one of these qualities, but only at the expense of all the others. I agree entirely with everything that Mr. Hale has brought out with respect to the very greatly improved cushioning, but my experience does not check with his on the subjects of power consumption, ease of steering and the puncture hazard. I believe that the motoring public is used to a certain standard so far as punctures are concerned. Anything that is done along the line of the balloon tire must be done with that in view. We cannot change to too thin a carcass and, on the other hand, if we thicken the carcass we must use higher inflation-pressures. I favor a middle course.

I have noticed that, so far as the difficulty of turning the car or the steering-wheel is concerned, there is not much difference in the heavier cars, but it usually happens that the wheel turns before the tire does. In other words, the flexibility of the tire carcass at the lower pressures permits the wheel and the rim to turn inside the tire. A certain "snapback" is evident after a corner is rounded, which might startle a driver who was not accustomed to it; it may be possible to overcome this, but I am not sure. So far as high-speed work is concerned, I am afraid of the large thin-section tire. I can take anybody out on the road and scare him to death at 60 m.p.h. I believe that the balloon-tire development is a good thing if it is not carried too far or pushed too rapidly.

W. H. ALLEN:—I drove here, 500 miles, on air-cushion tires and had a very comfortable ride. However, it seems to me that the tire is really a small part of the problem, and that the major development is for the automotive engineer, who must find out what this tire really contributes to a car and then get out of it what is there. We can experiment with tires but, without the cooperation of the automotive engineer, I think our chances of success are rather remote.

C. F. OFENSEND:—We have been conducting tests on certain sizes for some time. We feel that the narrow

[1] M.S.A.E.—Vice-President and factory manager, Goodyear Tire & Rubber Co., Akron, Ohio.

[2] M.S.A.E.—Technical assistant to the president, United States Rubber Co., New York City.

rim proposed by some is objectionable, and favor having the base as wide as that of the present rims.

H. W. SLAUSON:—The tire manufacturers have realized that some car producers have been over-sizing to the point where now possibly 2800 or 3000-lb. cars are using 4½-in. tires. They are now permitting an air-pressure of 40, 45 and 50 lb. per sq. in., dependent upon the load, on what Mr. Hale terms the high-pressure tires. We have already taken a step in the proper direction toward increasing the ease of riding on the old type of tire by reducing the air pressures in proportion to the load that they carry.

MR. HALE:—I was aware of some of the things that might come up from other tire members of the organization. It is only natural that there should be a difference of opinion on anything new. I have stated what we found to be our experience and we have tried to convey the idea that this is the result of a very extensive investigation. I will let it stand at that. Sooner or later the matter will simmer down to something. Whatever is the right thing will manifest itself and we will all arrive there. If I have been wrong I will be only too glad to admit it, but I can say nothing further except that everybody must bear in mind that developments are very rapid in the tire industry. Therefore, although some of these things seem to be rather startling, it, nevertheless, would be well to give them a trial, because they may happen to be right.

MECHANICAL BRAKING ON FOUR WHEELS AS A PRESENT AUTOMOTIVE NECESSITY

BY ALVIN M. YOCOM

THE author states that, when used in conjunction with the braking effect of the engine, two-wheel brakes work well in retarding a car on long or heavy grades, but that, for emergency stops, which are by far the most frequent, two-wheel brakes do not give a driver the positive control of the vehicle and the sense of security that are imparted by the retarding effect of braking on four wheels. The mechanical four-wheel braking-system manufactured by the company the author represents is described and illustrated, the claim being made that the front-wheel portion of the system can be connected and equalized with any of the present-day rear-axle or transmission brakes without discarding any of the rear-axle or transmission brake-material. The equalization of brakes is discussed in some detail, inclusive of foreign practice, and other features such as "fight" in the brake-pedal, the mounting of the steering-arms and the distribution of shoe pressure to prevent chattering and "grabbing" are considered.—[Printed in the July, 1923, issue of THE JOURNAL.]

THE RENAULT MECHANICAL FOUR-WHEEL BRAKING-SYSTEM

BY MARCEL GUILLELMON

THE high car-speed demanded by present-day drivers of automobiles is stated by the author as having necessitated braking systems that more adequately overcome the effects of such increased momentum than is possible with ordinary brakes applied only to the rear wheels. Since, at the time the brakes are applied, the greatest part of the weight of the car is thrown upon the front axle and the front wheels, he believes it imperative that brakes be applied also to the front wheels and demonstrates that this also prevents skidding as well as increasing the braking effect.

The four-wheel braking-system of the Renault car is then illustrated and explained in detail, and the advantages of this servo-brake system in regard to braking power, smoothness of operation and adequate car control, are set forth.—[Printed in the July, 1923, issue of THE JOURNAL.]

THE DISCUSSION

PRESIDENT H. W. ALDEN:—This meeting is in the nature of an open forum dealing with the subject of four-wheel brakes. The speakers who have addressed you were not invited here to exploit any particular type of four-wheel brake. They are authorities, however, on representative types of four-wheel brake and are here to aid in the general discussion of the subject. This is not in any sense a channel for any individual four-wheel-brake advocate to present his case for any commercial reasons, but the subject of four-wheel brakes is such a live issue that the views of these gentlemen are interesting, and the discussion from the floor that is to follow will be interesting also.

CHARLES L. SHEPPY:—Regarding the problems involved in the application of brakes to front wheels, the tests and the research work covering a considerable period of time show that the application of front-wheel brakes to the average car, *as of today*, cannot be considered safe. If the front-wheel brake has to be considered seriously for regular production, the following several items should have serious consideration in order that the application of front-wheel brakes will give additional safety to the vehicle and not prove a menace to the public. The most vital problems in the installation of front-wheel brakes are

(1) The front axle should be designed to withstand the torque due to front-wheel brakes
(2) Front springs should be of liberal width, should have an extra top leaf, should have a center bolt to dowel into the axle, should be well supplied with rebound clips, should have the smallest possible arch under load and preferably no arch under load
(3) Spring bolts, spring clips and shackles should be of liberal size and of first-class material
(4) The cross coupling steering-rod should be straight, if possible, and, where spring-backed ball sockets are used, they should have a very limited amount of travel, preferably none

(5) The steering-pivot axle should have liberal bearing surfaces and be of such design as to withstand the additional stresses imposed by the use of front-wheel brakes. The steering levers should be kept as straight as possible and be of liberal sections and first-class material

(6) Bearings of sufficient capacity should be selected. The additional stresses on the front steering axles require serious consideration as to the loads imposed on front-wheel bearings

(7) The steering-gear operation should not affect the operation of the brakes, and the operation of the brakes should not affect the steering-gear operation in any way

(8) Center-point steering is not essential in the application of front-wheel brakes, its only advantage being that there is less load on the cross coupling steering-rod

(9) Consideration should be given in regard to what interpretation the State authorities of the several States will place on four-wheel brakes as coming within the law of the States that require two independent and separate sets of brake

From the comparative figures given in Table 1 for two and four-wheel brakes, respectively, it is evident that the car of today, with only two brakes on the rear and with the front axle and the springs designed only to take care of the static loads, is not adapted to take care of the additional weight and torque imposed by the use of front-wheel brakes. The spring makers will no doubt experience some difficulty in developing a satisfactory spring that will take care of the additional weight and torque due to the use of front-wheel brakes and still maintain the desired easy riding qualities that are required today. It is understood that the stresses imposed on the front-axle and the springs, as a whole, can be kept below the comparative figures given by using less powerful brakes on the front wheels. It is felt that this is advisable.

The type of brake is a matter of choice; it can have external bands, internal bands or internal expanding shoes. The internal type with properly ribbed brake-drums gives a longer life to the brake linings because of the better heat-dissipation. External bands when used hard lose their clearance and drag due to the brake-drum expansion caused by the poor heat dissipation, because the band surrounds the drum and insulates or holds the heat in the drum. The internal brakeshoes should be made of aluminum, preferably, to help cancel the expansion of the drum. Proper care in the selection of the material is necessary, due to the extreme heat to which these parts are subjected. Temperatures of 600 deg. fahr. have been obtained in the shoes during the tests conducted. It is noted also that internal brakes do not squeal when applied, while, with external brakes, this is a general complaint. It is felt that four-wheel brakes, when properly designed with due consideration for a liberal safety factor, are a desirable addition; otherwise, they had best be left off.

H. M. CRANE:—As one of the members of the Council, I favored holding this session to bring out into the open the very difficult four-wheel-brake problem that was being urged upon many of our engineers and to discuss the difficulties of obtaining the results that are desirable if we are to secure improved stopping power on our cars.

It is my understanding that, at the Indianapolis race, the four-wheel brake was rather conspicuous by its absence. In the road races, however, its use has been practically universal. The reason, to me, is obvious. In the road races, the four-wheel brake is applied and used for the definite purpose of rapid retardation. The driver is willing to accept an increased weight and a poorer steering gear to get the increased retardation. In the Indianapolis race, there is no reason for sudden stopping during the actual running of the race, except in an emergency. When the driver simply had to consider emergency stops, he preferred to leave the extra trappings off and obtain the lighter axle and car weights and the better riding that came with a simple brake system.

I am glad that we have had a description of the application of the four-wheel brake to the larger cars, necessitating, as is apparent in European practice, the use of an auxiliary mechanism to apply the brake. The reasons for this were not explained, but they are extremely simple. If we start from the simplest form of brake, that is, the transmission brake, we have a single brake-band or two brakeshoes mounted directly on the power-plant with a short and simple linkage; there is no chance for spring in the linkage, and no necessity for equalizers. When we proceed to the rear-wheel brakes, we have double the number of bands or shoes, an increased amount of linkage and a certain amount of come-and-go in many designs, due to inaccurate connections as to the layout of the spring centers and the brake-operating centers, so that a certain amount of kick from the pedal is involved. We have the spring effects, possible lost motion and the fact that the brake-drums then are placed in a postion where they must be protected more or less against dirt and dust.

The next step is to brakes on the front wheels in addition. We again double the amount of brake-drums and

TABLE 1—TESTS OF STOPPING DISTANCES OF THREE DIFFERENT TYPES OF BRAKE APPLICATION

	Type of Brake		
	Rear, External-Band Brakes	Four Brakes, Internal Shoes	Four Brakes, External Bands
Total Weight of Cars, lb.	6,000	6,000	6,000
Total Surface of Brake-Lining, sq. in.	332.4	308.6	600.0
Weight per Square Inch of Lining, lb.	18.1	19.4	10.0
Stopping Distance, in Feet, at			
20 m.p.h.	35	23	15
30 m.p.h.	70	45	35
40 m.p.h.	113	74	60
50 m.p.h.	175	114	90

Comparative Figures Based Upon a Coefficient of Adhesion of 0.9

		Two Brakes	Four Brakes
Wheelbase, in.		138	138
Height of Center of Gravity from Ground, in.		36	36
Total Weight of Car, lb.		6,000	6,000
Weight on Rear Axle, Level Road	per cent	58.6	58.6
	lb.	3,500	3,500
Weight on Front Axle, Level Road	per cent	41.4	41.4
	lb.	2,500	2,500
Transfer of Weight, Wheels Locked by Brakes	per cent	14.0	23.6
	lb.	840	1,410
Transfer of Weight on Grades Expressed in Percentage of Road Length. On a Grade of, per cent,			
10	per cent	15.1	25.1
	lb.	906	1,500
20	per cent	16.6	27.1
	lb.	995	1,625
30	per cent	18.6	29.6
	lb.	1,115	1,775
Greatest Transfer of Weight from Rear to Front	per cent	18.6	29.6
	lb.	1,115	1,775
Weight Remaining on Rear Axle	per cent	40	29
	lb.	2,385	1,740
Maximum Torque Transmitted to Each Pivot Axle, lb.-in.		.....	31,000
Bending Moments, in.-lb.			
Vertical		.....	27,800
Horizontal		.....	25,000
Combined		.....	37,400

brakeshoes; we double the number of connections, double the number of equalizers and double the possible spring in the mechanism, for which last there is a great liability in cars having a 56-in. tread and a wheelbase upward of 140 in. The result is exactly as has been described; it is impossible to produce a four-wheel brake on any but a light car that will operate directly from a foot-brake pedal with satisfactory pedal-pressure without excessive pedal motion. I am perfectly willing to stand back of that statement, and I challenge any one to refute it. I am speaking now solely of the brake that operates directly from the pedal.

On the other hand, I have been driving a car that weighs 5500 lb. without passengers and is frequently loaded to 6500 lb., using a transmission brake that has two 12 x 2-in. drums installed back to back, in which the pedal motion is less than that of the clutch pedal and the pressure required to slide the rear wheels is less than that on the clutch. It is never necessary to lift the heel from the floor-boards to operate this brake sufficiently to apply the full braking pressure to the car: the car being very low hung and with all the weight thrown to the rear that is possible, the braking result is very powerful.

Malcolm Loughead suggests a method of determining the efficiency of braking in which the driver, by depressing the brake pedal, fires a pistol into the roadway. I think this is not a fair method of testing, certainly as regards emergency stopping. The only fair system in emergency stopping is for the car to be proceeding at a given speed with the driver's foot on the accelerator pedal and, at an unknown point, for an observer to fire a pistol into the roadway; that point should be the starting point of the stop and the distance should be measured from there.

I am convinced that, with most of the servo mechanisms, and with the attempts to handle foot brakes without servo mechanism by excessive brake-pedal action, the attempt of the driver to move his foot from the accelerator pedal to the brake pedal, as well as the time required for the servo mechanism to take-up and apply the brakes, largely will cancel the difference in the more rapid stop when the brakes have actually been applied. I advocate simplicity. The public is the user of the automobiles that we turn out; we are not building racing cars for experienced drivers. It is not the condition of the car when it leaves the factory that will count, but it is the condition of the car a year after it leaves the factory.

The Transmission Brake

I am sorry that, in our attempt to get the best braking, we have ignored more or less the possibility of the transmission brake. I have no special reason to urge the transmission brake except that I have used it for a long time. One other company has used it for a long time also and has shown that, in service, it is wholly possible to make the transmission brake do the work. It is the simplest form of brake and has the advantage that it is operating clear of mud and dirt; therefore, it can be run entirely exposed and much better cooling can be obtained than on other forms of brake. I admit that it will cost more to produce a good transmission-brake than it will to produce rear-wheel brakes but, when its simplicity is compared with that of any four-wheel brake, it is evident that it will be far cheaper and far simpler than the four-wheel brakes.

As to the small amount of wear-and-tear on the transmission brake, I can account for that only by the relatively clean position in which it is situated. My own car, used in city traffic and in heavy suburban traffic, was pulled down a year ago after having run 62,000 miles and the transmission brake-liners were not changed; it was not considered worth doing although the car was taken apart entirely. Mr. Masury had a car that was equipped with a transmission brake, an old experimental car; he pulled it down last winter and, believing that it would be necessary to replace the brake-liners, he ordered new ones and had them on the ground. When that car was pulled down, the brake-liners were not changed, although the car had been run more than 40,000 miles while in his possession and many thousands of miles before that. Along with this long life of the lining are the facts that it is very rarely necessary to adjust the brake and, because the brake is not connected to the road wheels, it is absolutely free from any pedal action on rough roads. It also is the only form of brake that approaches equalization. Mechanical equalization of brakes does not necessarily mean anything. When brake equalization is dependent upon toggle action, it is obvious that unless the angle of the toggle linkage is exactly the same in both sets of shoes, the variation in the shoe pressure will be very great between the two sides of the car. The factory can adjust brakes as carefully as is possible, but no one yet has been able to make brake-linings that wear uniformly on both sides. At the end of 6 months, one brake will be holding possibly 50 per cent more than the other one when an absolutely equal pressure is being applied to the mechanism. No one yet has been able to manufacture a brake-lining that has uniform coefficients of friction. We all know from practical experience that the condition of the brake-lining in a car varies greatly from day to day when driving; undoubtedly, it varies greatly from side to side of the car, depending upon the amount of road dust and oil that it has absorbed.

I wish to make a plea for not throwing away anything that we have today that pertains to the steering safety of an automobile for the sake of securing an increased stopping efficiency. In building one of our cars, 10 years ago, we had a reactionary owner; he was a man 70 years of age and he insisted on having cushions that were 18 in. high; he insisted also on having high backs, with the tops tilted-up instead of lying flat and other things that were then out-of-date about 5 years. He also insisted on having clincher tires at a time when everybody else was using the demountable rim. The result was that his car was safe to drive at practically any speed on almost any kind of road without shock absorbers. The front wheels hugged the ground closely and maintained the steering. Exactly the same model of car, equipped with demountable rims and weighing possibly 50 lb. more on the front axle, felt extremely unsafe on the parkway at the same speed that this first car was perfectly comfortable to drive. It was necessary to use damping devices to obtain equal confidence in steering.

Ultra-rapid motion-pictures show that the front wheels of a car actually leave the ground for long spaces. This action is bound to be increased greatly by every pound of weight that is put into the front axle for a given weight above the springs. From what Mr. Sheppy has said, it must be obvious that a very great increase of the front-axle weight will be required by front-wheel brakes if they are to be at all satisfactory or even safe to use. Another feature of the riding at the front end of a car is a periodic vibration that is produced by the throw of the axle mass, including the wheels and the knuckles, between the tire and the springs. There is a relatively heavy weight that is being tossed up-and-down, with a

spring below it and a spring above it. The greater the weight is, the worse this condition is. In shaft-driven cars, I think we have all noticed that, at times, the rear end of the car seems to get up in the air and float, on a washboard or cuppy road. At such a time, there is mighty little control of the car. If we have the same thing applied to the steering end of the car, we have no control of it at all.

I am not a pessimist about four-wheel brakes, but I do know that there are some very serious problems involved with their application on account of the public. I dislike to see the automotive industry rushed into their production before it has had ample time to work out all the problems and to make perfectly sure that, when the car having four-wheel brakes is put on the market, it is as nearly perfect as our present engineering skill permits.

PRESIDENT ALDEN:—Those of us who have studied this front-wheel brake proposition are not altogether sure that we know just yet what we do want. The company I am connected with has been working at it for some time. While we propose to build four-wheel brakes if the time comes when that is absolutely necessary, we intend to take all the time that is needed to get them right.

C. T. MYERS:—I agree entirely with Mr. Crane. On the one hand it seems that, with four wheels, we should use the available tire contact for braking, but it will be a long process before we can effect satisfactorily the compromises that will be necessary to adapt four-wheel brakes properly. The point brought out by Mr. Crane that good design is the acme of simplicity should never come off the wall of any drafting room.

W. P. KENNEDY:—We ought to follow the principles laid down by Mr. Crane in being cautious at first and progressing cautiously afterward. If four-wheel-brake mechanism were to be used entirely by skilled operators, there might be very little risk about it; but, considering it as a trade and a manufacturing development, I think we are courting much trouble from the operators' and service standpoint and considerable misplaced investment from the viewpoint of the manufacturer.

W. G. WALL:—It appears to me that the die already has been cast. Considering the number of cars that are now being equipped with four-wheel brakes, we will certainly have to make the best of the proposition as it is. I favor four-wheel brakes. When designed and equalized properly, they certainly are a wonderful addition to any car. I have been driving with four-wheel brakes for the last 2 or 3 years. The most important question is whether four-wheel brakes can be kept adjusted. We know we can equalize them and adjust them perfectly so that we get very fair results for a short length of time, but there are so many problems that enter into the perfect equalizing of the four-wheel brakes that any one of many different things can happen to those brakes which will prevent them from being perfectly equalized and adjusted. All those that I have seen that have run several months without any attention have a tendency to show-up very differently from ordinary brakes. The adjustment may have been perfect and the design may have been as good as we now know about but, after a few months' use, especially over tar roads, dirt roads and muddy roads, they do not act as well as the ordinary brake. When I say "act well," I do not mean that they do not stop the car, because they always stop the car better than two-wheel brakes.

In connection with the design of four-wheel brakes, there are several things that we all must think about. Are we making our front axles in the proper way for these brakes? In general, we have come to think of the ordinary I-beam section as being the final word on front axles, but it is possible that we may have to design our front-wheel axles to take-up entirely different strains from what they have been accustomed to, and that some other type of section may be preferable. Theoretically, the tubular section probably would answer better. The car equipped with four-wheel brakes, if they are designed simply, with the transmission brake for an emergency, makes a wonderful driving proposition, but I agree with President Alden and Mr. Crane that we still have much to learn, not only about the design but about the application and the maintenance of four-wheel brakes.

JOSEPH A. ANGLADA:—Mr. Wall has stated very clearly exactly what my ideas are on the subject.

DAVID BEECROFT:—There has been the suggestion of a feeling at this session that sales considerations will be the dominating and the determining factor in regard to four-wheel brakes. Here is an opportunity for the members of the Society to take a stand for what they believe is right. If, in the past, the sales end has dominated more than have the engineers, I think we are now at a time in the history of the automotive industry when the engineer has an opportunity to be the safety-valve in this braking situation. From the public's point of view, there is great magnetism in the name "four-wheel brakes," and a great desire on the part of the public for them. We should conserve the best interests of the industry. I have ridden considerably in cars equipped with different kinds of four-wheel brake, but they were all beautifully set-up by the factory people and kept so for demonstration purposes. If we could always depend upon that adjustment, well and good. This is a time when the engineer really can stand-up for what he thinks is right. If you, as engineers, feel that four-wheel brakes are not generally desirable, have the conscience and the backbone to tell those with whom you are working that the engineers are not ready to take this particular stand. It will be much better for the reputation of our industry.

ALBERT J. GIFFORD:—Is it a fact that fully half of the European continental firms offer four-wheel brakes as standard equipment? If so, what success is that policy having and why is it that we in the United States are slow to adopt four-wheel brakes when they have been adopted in such a large degree in Europe?

MARCEL GUILLELMON:—In France, most of the cars manufactured in production have four-wheel brakes. There being no speed limit, one naturally drives much faster in France than in the United States. But, although the public drives at high speed, it desires the safety afforded by the cars equipped with four-wheel brakes and demands them from the builders. Evidently it means a considerable expense to add brakes to the front wheels, and especially to add a servo-brake. In Paris, the authorities are now studying the possibility of obliging all the taxicabs to adopt front-wheel brakes. In 1922, the Renault Co. delivered about 4000 taxicabs and, most probably, will now be compelled to equip them with front-wheel brakes, which would involve a large amount of work due to the necessity of changing the front axles, the springs and the like. Of course, this is a great expense for the taxicab company, but nothing should be spared when the safety of the public is concerned. About 75 per cent of the cars of 10 hp. and up, manufactured in production in France, are equipped with four-wheel brakes. The cars built by Renault, Panhard, Chenard-Walker, De Dion and Delage have front-wheel brakes on all models of 10 hp. and up.

MR. LITLE:—I am a believer in four-wheel brakes from the standpoint of safety. I think they will be put on all cars sooner or later. However, the great fear of some of us is that we will be too precipitate and put them on before they are perfected. It is conceded that most of the automobile accidents are due to inefficient brakes; either the brakes are not adjusted properly or they are not adequate for the car. Four-wheel brakes certainly help that situation.

I do not agree with Mr. Crane when he says that four-wheel brakes cannot be applied without a servo attachment or some auxiliary attachment to build-up the power. If they are of the external type, I believe that four-wheel brakes are perfectly feasible and practicable without any form of servo attachment. From a rough estimate, it seems that it takes about three times as much effort to apply internal expanding types of brake as it does the external brake that is designed properly. If advantage is taken of the tightening effect of an external brake, it can be used with a four-wheel brake to very great advantage and will require very little pedal-pressure. I think it is merely a matter of brake design and hook-up. The trouble with most of the four-wheel brakes of today is improper equalization. We have examined all of the mechanical and the hydraulic types of brake and have tried them out pretty carefully. I believe that proper equalization is our great problem. I think that four-wheel brakes are coming.

L. H. POMEROY:—I call attention to the essential difference between the external contracting and the internal expanding brake of the shoe type. The external band-brake is a wrapping type of brake; whereas, the internal expanding-shoe type is analogous to a plate clutch where there is a direct pressure between the friction surfaces.

The calculations applying to an external wrapping-type brake are identical with those determining the frictional contact between a belt and a pulley. The relative tensions of the tight and the slack side of the belt are given by the formula

$$T_1/T_2 = \varepsilon^{fa}$$

where

a = the angle of contact between the belt and the pulley
$\varepsilon = 2.7128$
f = the coefficient of friction
T_1 = the tension of the tight side
T_2 = the tension of the slack side

It will be seen readily that the coefficient of friction is an exponent in the above equation so that the variation in the belt tensions and therefore the driving capacity of the belt varies to a greater extent than that of the coefficient of friction itself. The result is that, in the average external band-brake construction, a variation in the coefficient of friction of from say 0.25 to 0.33, that is, 33 per cent, produces a variation in braking effort of some 54 per cent.

So far as the internal expanding brake of the shoe type is perfectly rigid, so far is the braking power only directly proportional to variations in the coefficient of friction.

The trouble with an external brake seems to be that it is as difficult to design it so that it will always work, as it is easy to design it so that it will sometimes work. The internal expanding-shoe type has, in some respects, more problems; but, with good design, it can be made very powerful indeed and even with poor design it functions to some extent, whereas it is by no means unknown for the external wrapping-type of brake not to function at all.

After studying the subject of the internal brake for many years, I feel convinced that the secret of the design lies in extreme rigidity. In fact, given a choice between a brake of large diameter that was not rigid and a brake of small diameter that was as rigid as possible, I would unhesitatingly choose the latter. In this respect, the advantages of aluminum are very manifest. One is enabled to put deep ribs around the brake-drum without involving serious weight; it may be remarked that deep ribs should be tied together by cross-ribs at intervals, so that the circumferential ribs shall not distort like a piece of paper being bent edgewise. With a cast-iron insert, a brake-drum can be produced that is light and rigid and possesses great power of heat dissipation. My experience with such drums during the past 3 years has been that the brake-linings have stood up for 55,000 odd miles and show remarkably little wear indeed, although used under the most severe conditions. The necessity for rigidity applies also to the brakeshoes, which should be made just as stiff as it is possible to make them. This stiffness can be obtained with very little increase in the weight.

It seems very doubtful whether a servo-brake mechanism is required except for the heaviest type of car. The brakes to which reference has been made herewith are operated by spiral cams, giving an approximate leverage of 250 to 1 between the pedal and the brakeshoes. A motion of 2 in. on the hand-lever or the brake pedal will lock the brakes completely. This result, of course, means careful workmanship, but it is easily obtained by a grinding operation on the brake-linings themselves when the rear axle is completely assembled.

FOUR-WHEEL BRAKES IN ENGLAND

So far as I am acquainted with the English four-wheel-brake situation, this differs only from that in America to the extent by which the English are following the French more closely. The participation of English racing cars in the races in France brings English engineers into contact with cars having front-wheel brakes. The lessons learned at a race always seem very much more emphatic than those that are learned by many times that amount of ordinary road work. In England there are certain companies that are fitting a front-wheel brake. Some are putting it on as an optional device and I think they are putting on a good many. The actual movement has not gone very far because the automobile industry in England has been very sadly crippled during the past several years. However, I have no doubt that the front-wheel brake will become just as popular in England as it will in the United States.

One finds, all through the United States, a movement from something that has been tolerated because there has not been time to change it to something that is the very best that possibly can be. I think the same thing will happen with the four-wheel brakes. I have yet to find any real American engineer who can champion the average American rear brake. The four-wheel brake that can be built in quantities and therefore built cheaply will remove possibly the last material criticism of the American car as it now stands. It seems to me that the position we must take as engineers is not whether we are to have four-wheel brakes or not, but that we will have them and that it is our business to get them as quickly as we can, consistent with the necessities of the case.

MR. LITCHFIELD:—The importance of the question of extra braking facilities increases as we go up to greater weights and higher speeds. It will be especially interesting in the field of passenger carrying, in trucks and buses and vehicles of that nature. I call special attention to the braking facilities on the truck designed by

the Army; it has four drive-wheels mounted on an oscillating truck and the four-wheel braking-system. The results obtained in braking heavy loads running at high speeds are remarkable.

C. M. MANLY:—The mere fact that the four-wheel brake problem is difficult is the very reason that all the more attention should be paid to it and that the work of its solution should be got under way as early as possible. The difficulties of the problem should not deter engineers from tackling it.

DAVID FERGUSSON:—I have read with much interest the recent papers and discussions on four-wheel brakes that have been presented before the Society, and I am rather surprised that the advocates of four-wheel brakes have not stated the obvious fact that four-wheel brakes do not increase the static load on the front axles and the front springs over the load imposed by rear-wheel brakes capable of locking the rear wheels, when the deceleration is the same in both cases. Also, in holding down the speed of the car on a hill of say 10-per cent grade to 15 m.p.h., the car with four-wheel brakes does not impose any greater static load on the front axle than does the car equipped with rear-wheel brakes, under the same conditions. Four-wheel brakes only impose a greater static load on the front axle when they are used to give a quicker deceleration than can be obtained with rear-wheel brakes.

I am inclined to think that four-wheel brakes capable of locking all wheels rarely will be used to stop a car in the least possible distance except to avoid a fatal accident, because such rapid deceleration, approximately double that of rear-wheel brakes only, is not only uncomfortable to the passengers but may actually injure them unless they are prepared for the stop and have something substantial to hold on to. A stop from a speed of 30 m.p.h. within 70 to 80 ft., which can be accomplished with a car fitted with rear-wheel brakes only, is as quick as should be indulged in under ordinary conditions unless the driver is alone in the car, since he has the steering-wheel to brace himself with. A deterrent to making a quicker stop of the average car than that is the danger of being run into by the car behind; this obtains in the majority of brake applications for city usage. The average driver of a car equipped with four-wheel brakes will not make quicker stops than he could make with a car having rear-wheel brakes only, in more than perhaps 5 per cent of the decelerations he effects. This indicates that the increased load upon the front axle is incurred very rarely.

I have driven cars equipped with four-wheel brakes that were capable of locking all wheels, making stops in the least distance possible without causing the front-spring bumpers with which the cars were equipped to strike the under frame violently, but these same cars would strike the bumpers most violently when run over a depression in the road at high speed, showing that the front-wheel brakes did not impose as great a static load on the front axle and its parts than already had to be provided for.

Most conditions in connection with the application of four-wheel brakes can be met very easily, though only by added complications. There are, however, some problems that present difficulties such as (*a*) the avoidance of locking the front wheels when making a turn with the brakes applied; (b) the maintaining of sufficient travel of the foot-brake lever after taking up the slack to leave still enough travel to apply the brakes properly after a little wear has taken place and (*c*) the provision of sufficient leverage to apply all four brakes fully, without undue effort, where no assistance from complicated servo attachments is used.

This problem is exceedingly great in the case of heavy cars as, with rear-wheel brakes only, it is difficult to provide sufficient leverage to lock the wheels easily and maintain sufficient travel for the brake-pedal. With the same leverage, double the pressure on the pedal will be necessary to lock the front and the rear wheels, and there will be double the slack to take up. This may result in the necessity for frequent brake adjustments, even though the additional front brakeshoe surfaces may give double the total area to that used in the case of rear-wheel brakes only. Additional problems are (*a*) the provision of a simple means of adjustment for wear on each brakeshoe that can be made quickly and easily by the average driver and (*b*) the maintenance at all times of proper equalization.

IMPORTANCE OF BETTER AUTOMOBILE HEAD-LAMPS AND PROPER ADJUSTMENT

BY R. N. FALGE AND W. C. BROWN

THE accurate construction and easy adjustability of automobile head-lamps, though they have received much attention, are still susceptible of further improvement. If motorists realized that the road would be illuminated better, objectionable glare could be avoided and a better and safer head-lamp would be secured by properly adjusting the head-lamps now in service, an immediate and far-reaching improvement would be effected.

Views are given of tests made with the common type of head-lamp with a parabolic reflector to show the effects produced by placing the source of light at the focal point, by moving it forward, backward, above and below this point, and also by cylindrical flutes in the glass and by horizontal prisms. The head-lamp is shown to be very sensitive inasmuch as the distances from the filament to the reflector are very short when compared with those to which the light is projected. A type of lens is described that will compensate for the commercial variations in the position of the filament and at the same time distribute the light effectively, converging or diverging the rays laterally while maintaining the top or cut-off substantially at the level of the head-lamp. As the maximum intensity should be placed as near to the top as possible to illuminate the road-bed most effectively, and as the eye accommodates itself slowly to changes of intensity, the lens takes advantage of these characteristics by spreading and bending the light in each zone by different amounts.

The requirements are given for the uniform and satisfactory service of lamps and of such parts as filaments, sockets, reflectors, lenses, doors and mountings, the underlying idea being the use of devices that will obviate the necessity for focusing and leave to the motorist only the simpler adjustment of aiming.—[Printed in the July, 1923, issue of THE JOURNAL.]

THE DISCUSSION

DR. C. H. SHARP:—The head-lamp situation is of vital importance to the automobile industry. If head-lamp conditions on the road are not improved, laws regulating

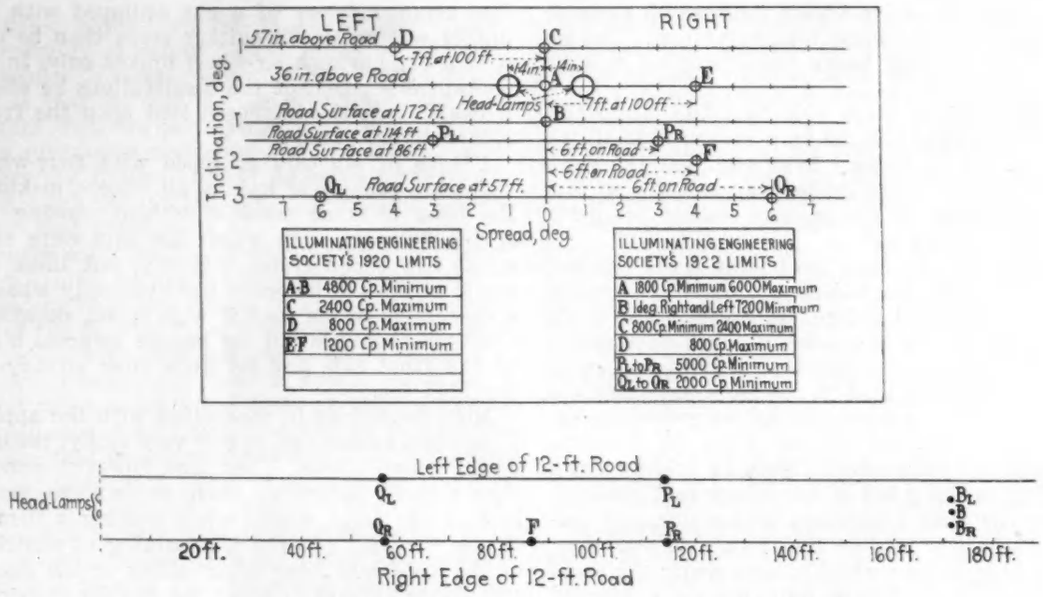


FIG. 1—BEAM LIMITS FOR THE LABORATORY TESTS OF HEAD-LAMPS

such conditions are likely to become more drastic and the more chances there will be for trouble that will react directly upon the whole automotive industry. Much has been done in the guidance of legislation bearing upon this question. This has been done to a large extent jointly by the Lighting Division of the Standards Committee of the Society, working with the Committee on Motor-Vehicle Lighting of the Illuminating Engineering Society that took up the question about 6 years ago and has been working at it from the illuminating engineering point of view. The result of the work of these committees has been to formulate testing specifications for the approval of head-lamp devices and in putting such specifications before the State officials who have this regulation in hand, giving them thereby a rational means for going ahead with their regulatory functions. The diagram of approved practice in road illumination, Fig. 1 of Mr. Falge's paper, is very similar to the diagram that describes the official tests for approval of head-lamp devices to go on the road. This system of regulation has gone a long way in this Country. Many of the largest States have adopted it. Some of them, notably California, have incorporated it directly in their law. Others have taken it up through the operation of their administrative officials.

The most recent progress along these lines has been in the adoption of this system by the Conference of Motor-Vehicle Administrators of 11 of the Eastern States, covering New England, the Middle States and the State of Ohio. These administrators have determined among themselves that they will approve devices only after they have passed this standardized test which, by the way, has been adopted by the American Engineering Standards Committee as an American Engineering Standard. They will approve devices only after having passed this test, and then only after the device has been given a joint consideration by the administrators. When specifications of this kind were first brought out, they were made very lenient. It was a matter of common sense and good policy to do so. Since then, as a result of greater experience, they have been tightened-up and improved all along the line, and the latest form in which they exist and which has been approved by the American Engineering Standards Committee was adopted in 1922.

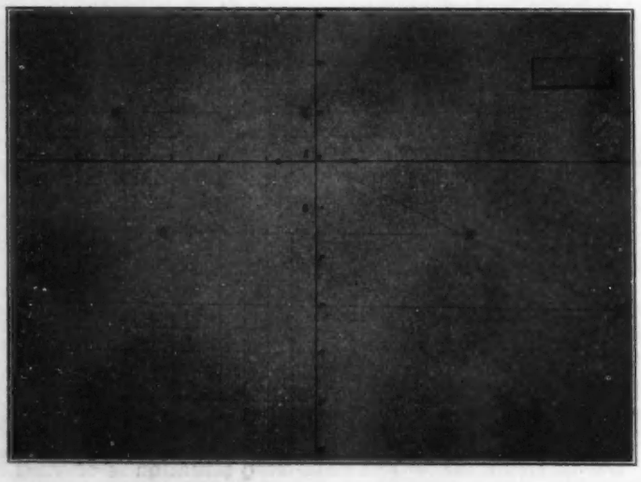


FIG. 2—BEAM PATTERN OF A DIFFUSING LENS THAT WAS IN USE WHEN THE EARLY SPECIFICATIONS WERE DRAWN UP

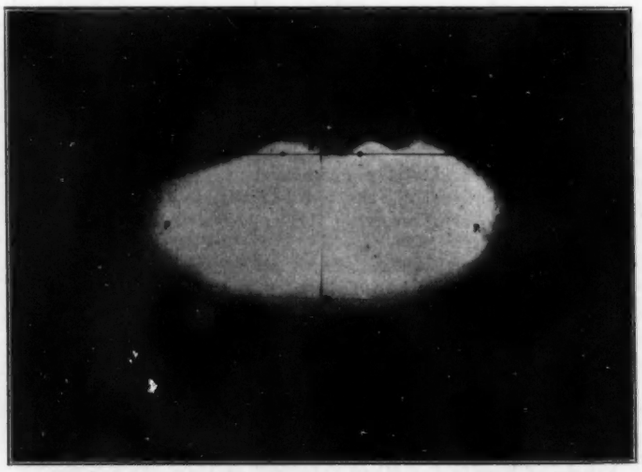


FIG. 3—THE EFFECT ON THE BEAM PATTERN OF COVERING THE UPPER HALF OF THE LENS AND PULLING THE LAMP BACK

Under the older specifications, many devices were approved by the States but, owing to the adoption of the later specification and to the consideration of the matter by the Committee of the Motor-Vehicle Administrators, a very large number have now been weeded out. Under the older standard, the beam had to be deflected downward, but there was no special requirement that the beam should be spread laterally. The later requirement has introduced this lateral spread.

The beam limits shown in Fig. 1 are those for the laboratory test for approval of types according to the standard specifications. Fig. 2 shows the beam pattern of a very well-known type of diffusing lens that was in use at the time the early specifications came out. Fortunately, this inefficient device falls far short of meeting the present specifications. Fig. 3 shows the effect of the covering-up of the upper half of the lens and pulling the

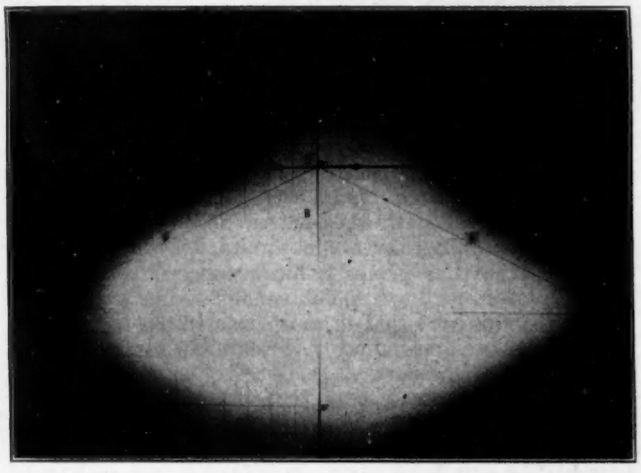


FIG. 4—THE BEAM PATTERN OF AN EARLY PRISMATIC LENS

lamp back. That produces a beam pattern which brings in the points R_l and P_r, but does not include these wider spread points of Q_l and Q_r. Fig. 4 shows the beam of one of the prismatic glasses of earlier days that is subject to the difficulty mentioned for Fig. 3. It is now obsolete. Fig. 4 shows that the lateral spread of the beam was not great and it threw a great amount of light near the car where it was ineffective and objectionable on account of glare.

Fig. 5 shows the beam of another device that might

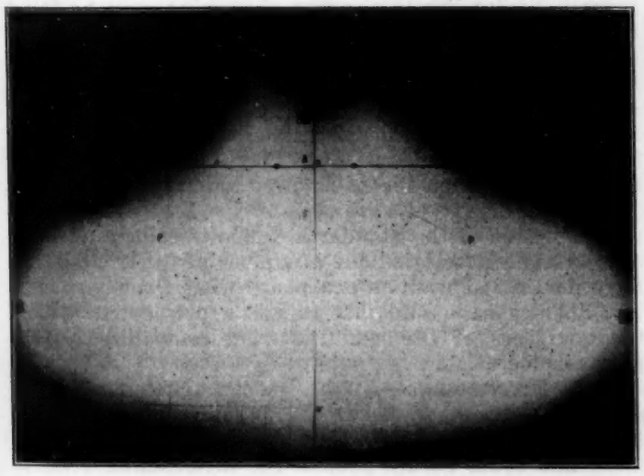


FIG. 5—THE BEAM PATTERN OF ANOTHER EARLY LENS

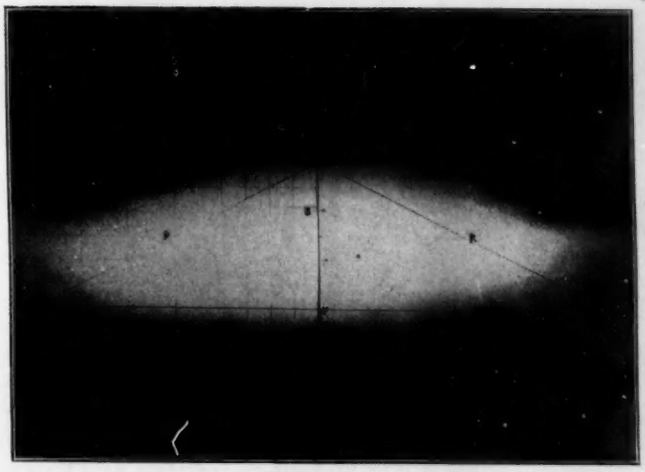


FIG. 6—DISTRIBUTION OF LIGHT FROM AN APPROVED HEAD-LAMP

come in, but that has been improved greatly since that time to bring it into accord with the modern requirements. Figs. 6, 7 and 8 show the beams of modern front glasses all of which are approved and are good, although they show definite individual differences. The "best" for any driver is the one that he himself prefers. Fig. 9 shows a beam that is cut-off very sharply above and below. This is open to certain objections in that it does not give enough light in its upper portion. It is not safe to have a device that has too sharp a cut-off. There must be some light up where the branches of the trees are, where the load of hay begins above the wagon wheels and in similar places.

FIG. 7—BEAM PATTERN OF A MODERN HEAD-LAMP

Table 2 gives a few figures on the results of testing operations for States under these various specifications. The figures given are taken from the records of one testing organization only. Table 2 shows that in 1918, under the several specifications for New York State, 86 devices were tested and 55 were approved; for Pennsylvania, 107 were tested and 80 approved; for Connecticut, 68 were tested and 52 approved. Then the specifications were made slightly more rigid. In 1920, for New York State, 28 more devices were tested and enough were approved to bring the number up to 92; for Pennsylvania, 8 more were tested and all were approved, making a total of 88; for Connecticut, 9 more were tested; Maryland shows 66 tested and 57 approved. Massachusetts had a slightly different specification. The authorities tested

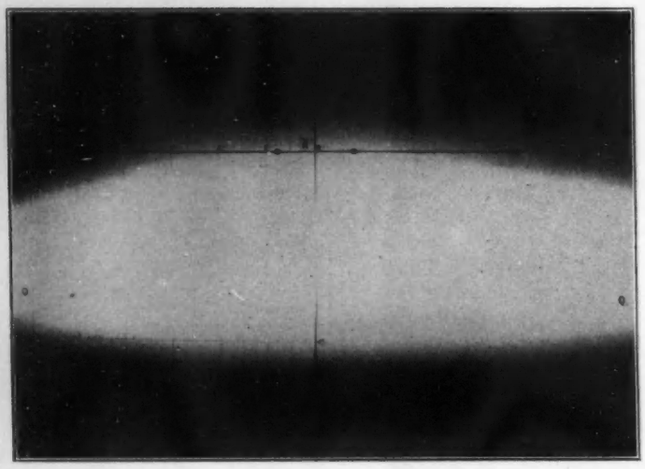


FIG. 8.—BEAM PATTERN OF ANOTHER APPROVED HEAD-LAMP THAT IS NOW ON THE MARKET

58 and 32 were approved. Under the recent action of the Motor-Vehicle Administrators working under the latest specifications, only 22 of the whole lot have been approved. Many of these earlier devices were never manufactured; they were impractical and useless. Others were subjected to some redesign that brought them under a new form number and thus brought them under approval; so, in Pennsylvania, the reduction from 98 to 22 does not represent a mortality of good things. Of all the things that ought to have died, a great many of them were already dead when this action was taken.

TABLE 2—RESULTS OF TESTING OPERATIONS

	Specifications for				
	1918		1920		1922
State	Tested	Approved	Tested	Approved	Approved
New York	86	55	28	92	22
Pennsylvania	107	80	8	88	22
Connecticut	68	52	9	47	22
Maryland	..	..	66	57	22
Massachusetts[1]	..	..	58	32	22

[1] Massachusetts specification for 1920; 1922 specification was the same as the other States.

Your Standards Committee's Lighting Division and the committee of the Illuminating Engineering Society have done good work that has been accepted by the States. It is a rational system for handling head-lamp

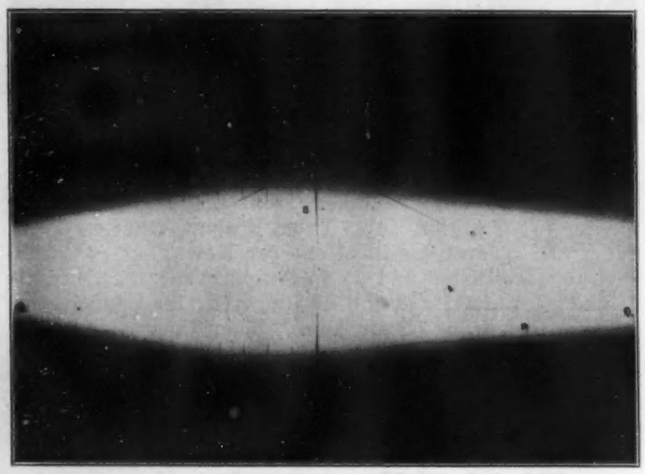


FIG. 9—DISTRIBUTION OF LIGHT FROM A LENS IN WHICH THE BEAM IS CUT-OFF VERY SHARPLY ABOVE AND BELOW

devices, but the committees cannot do very much more. From now on it is a question of the enforcement of the law, of the education of the men who drive cars and the men who build cars. The work that the committee has started and brought a long way should now be taken up by the individual members of the Society. The system is not perfect but it is a good one and the members of the Society ought to try to get it going. The sooner a general observance of the questions of focusing and aiming of good head-lamp devices is obtained through the general enforcement of the law as it exists, the quicker the industry will be insured against some drastic action on the part of the State authorities.

The engineers connected with the manufacturing companies can do much by seeing that good head-lamp devices inclusive of front glasses, good reflectors, good sockets, lamps that are put together right, and lamp supports that will stay adjusted, are put on their cars. All of those details come right up to the manufacturing end. No one can take up the work of these committees and push it forward to a successful conclusion better than the engineers who are connected with the manufacturing companies throughout the Country.

CHAIRMAN B. B. BACHMAN:—One point brought out by Dr. Sharp is particularly pertinent in that all of us who are engaged in the construction of vehicles are vitally concerned with the matter of uniformity. The dissimilarity of regulation in the various States is the one thing that has given us much concern; certainly it is one reason why we should endorse and support an activity of this sort that is acceptable to the authorities. As engineers, we are concerned with the formulation of regulations of this sort.

ALFRED REEVES:—The manufacturers are keen for laws that will make for the safe use of motor cars on the highways, and they desire to equip their machines so that they will come within these laws. I have always had a very high opinion of Commissioner Dill, of New Jersey, and his fairness in dealing with these matters. However, I call Mr. Shanley's attention to the fact that materials for motor cars are purchased a long time ahead. Our legislative department endeavors to keep the manufacturers informed of proposed changes in legislation. Most of the laws passed allow a certain amount of time for changes to be made and that is just what we would like to have done in connection with the lighting equipment. We need time in which to decide what should be required of automobile lighting, and then the manufacturer should be allowed time in which to comply. Our great difficulty lies in the fact that what may be legal in one State is not legal in another. The recent offer of Commissioner Dill to secure some uniformity along these lines will have universal support. Ten States, I believe, are planning to cooperate with him in preparing proper legislation. If they will tell us their requirements, I can assure them of the finest kind of cooperation from the engineers and from the automotive industry.

A. D. T. LIBBY:—I have been on the Electrical Equipment Division of the Standards Committee for a number of years and have tried out a number of different head-lamp devices. I want to emphasize what Dr. Sharp and Mr. Shanley have said that this is a problem to which the engineers of the manufacturing companies should give consideration.

E. C. CRITTENDEN:—At the Bureau of Standards, we are asked repeatedly what the best head-lamp device is. We cannot answer that question because we do not know and could hardly publish the information even if we did know. It depends to a great extent upon one's

preference as to the distribution of light on the road. It also depends somewhat on the speed at which one drives. There is a widespread interest not merely to know what the best device is but in the possibility of devising a formula that can be used by the authorities everywhere. We have many such inquiries from State and city authorities who wish to put into effect some kind of regulation. Fortunately, we felt entirely justified in recommending these requirements concerning which Dr. Sharp has spoken. It is not generally known how much labor has been spent in devising these regulations. Engineers of the Society, as well as those in the Illuminating Engineering Society who were considering the matter, have spent many an evening on the roads, actually trying various devices to determine what limits are reasonable. There are wide variations of judgment as to what is reasonable. Regarding light that blinds the eyes of another driver, when that work was started some years ago there was one engineer who insisted that any light of more than 100 cp. should be forbidden. The compromise finally reached was eight times that amount of candlepower. Many people expressed their judgment; the Committee adopted a value that seemed to be tolerable and attainable by available commercial products, for the commercial situation must be considered.

The view we have taken at the Bureau in dealing with the subject is that uniformity of requirements among the States is essential, although reasonableness and practicability are equally important. We invariably refer State and city officials to the current specifications that have been worked out jointly by the Society and the Illuminating Engineering Society. This development of joint action among the Eastern States is a most hopeful sign, and is an outstanding example of most effective cooperation between State officials. So far as the approval of types of device is concerned, it seems to me that we have gone as far as there is any use of going at present. We cannot expect now to get requirements that will be more satisfactory than those now established. Nevertheless, the report comes time and again that conditions on the road are worse than they used to be. That is probably because there are more cars and the improvement in the adjustment of the lights has not been great enough to counterbalance the growth in their number. I believe that the average car is in better shape than it was a few years ago so far as lighting is concerned, but there is no doubt that conditions have not improved as much as was expected, and that is largely because this approval of devices is only the first step. In fact, some of the approved devices often are worse than a plain glass would be, so far as throwing light in the eyes of another driver is concerned. I say that deliberately; some of them are worse than nothing if they are not adjusted properly. Moreover, a majority of them are not adjusted properly.

To bring the subject before the police authorities in the District of Columbia we made inspections recently on some 400 cars. They were taken at random as people came in in response to an invitation. Of these 400 cars, our men who made the adjustments considered that between 5 and 6 per cent really had their lights adjusted properly. Around 30 per cent had them in fair shape and more than 60 per cent were positively bad. Of the new cars, those that had been in service 3 months or less, the percentage that were bad was nearly as great as on the old cars. In other words, of the cars that came out from the dealers within the previous 3 months, more than 50 per cent had lights that were positively glaring. That is somewhat of a reflection on the men who build and sell cars; they should see that lights are in proper condition to begin with. Our view is that the next step to be taken is that of education, not merely of the builders and the dealers, but of the driver who must keep lights in adjustment and of the garageman so that he can assist in it. One difficulty is that there is no profit in it; the ordinary garageman is not concerned with spending time on a car unless he gets some profit out of it. He feels that he cannot charge enough for adjusting lights to make it worth his while, therefore he will not bother about it. That is the point of greatest difficulty at present. If the Society and other organizations can make arrangements that will make it appear worthwhile to the average garageman to give more attention to this problem, either through direct pay for the work or through emphasizing that a gain in good-will and in advertising ought to pay for it, progress can be made, but the next step is this campaign of education and the Society is in a strong position to help it along.

MR. CRANE:—What is the best opinion about the use of properly adjusted head-lamps? In other words, if one is driving a car with properly adjusted head-lamps on a road insufficiently illuminated by other means, is it believed to be necessary to shut off those head-lamps or to dim them on meeting another car? In the vicinity of New York City, it has been customary for some years with many people to dim their head-lamps or to cut them off on meeting other cars and, in my opinion, this results in a highly dangerous condition that frequently leaves both cars with insufficient driving illumination. So far as I know, no laws have taken cognizance of this point, except in Massachusetts, and I know of no regulations on the subject.

JAMES J. SHANLEY:—There is no obligation on the part of any driver to dim his lights anywhere in New Jersey and no such legislation is contemplated. My opinion is that a driver should not be compelled to dim his lights. I see no necessity for it if there is a proper device on the car. With dimmed head-lamps, there is altogether inadequate vision of the road.

PROF. R. C. GOWDY:—I have been interested in head-lamps for several years and have done considerable road and laboratory testing. As a result of this experience I believe that adequate spread and uniformity and smoothness of distribution are the most important factors in road illumination. More attention should be paid to the *S* points in the S. A. E. Recommended Practice for Head-Lamp Illumination; that is, to the light on the road 43 ft. ahead of the car and 9 ft. on the side. I am not sure that the present values should be included in the legal requirements, but these points should be kept in mind when engineers are selecting devices with which to equip their cars. Uniformity and smoothness of distribution are essential, particularly on rough roads.

The automotive engineer is interested in making cars pleasing to his customers. The psychological effect of adequate and pleasing lights that are comfortable to drive with has much to do with the pleasure that the user obtains from the car. Mr. Falge mentioned that the two things that go wrong with head-lamps are the aiming and the focusing. I do not know that the aiming feature can be cared for automatically, but I think the focusing problem can be solved. It is, as Mr. Falge has shown, perfectly possible to design lenses that will be self-compensating to a certain extent, and the same is possible with diffusing reflectors. The compensation, of course, is limited to certain tolerances or variations.

It is only through the efforts of the head-lamp manufacturers that this problem can be solved in this way,

but it is a fact that lamp manufacture has been carried to a point where bulbs are made with sufficient precision so that the focusing feature can be eliminated. The sockets can be fastened rigidly into the reflector so that replacement requires simply the putting in of the new bulb, which must be of sufficiently high quality to come within the tolerances for which the reflector is designed. This eliminates the focusing feature by making it a fixed feature so far as mechanical design is concerned and taking care of the variations in the bulb by optical design. The lens device will accomplish the result by a somewhat different means, but both of them tend to eliminate the focusing that is, perhaps, the most prevalent source of trouble. The aiming is a matter of education and, if sufficient importance were laid upon it, the public would finally find out how to aim a lamp if not how to focus it, for the latter is a somewhat more difficult operation.

W. A. McKAY:—As a member of the Lighting Division of the Standards Committee, I have been very active for a considerable period in working with the Illuminating Engineering Society on these matters of specification and test. We feel that the specifications developed are good specifications and that the devices which meet them will certainly give very satisfactory road illumination. Perhaps we have not talked enough about this before this meeting; however, I hope that as a result of this meeting you will take this problem to heart. The Lighting Division believes in the specifications; they were worked out after very thorough tests. We would like to have your cooperation and I feel sure that you will give to us greater cooperation.

ECONOMIC MOTOR-FUEL VOLATILITY

BY STEPHEN M. LEE

THE paper is a progress report supplementing a previous report made by R. E. Carlson on the same subject and covers further investigations made by the Bureau of Standards to secure data that can be used as a basis for estimating the effect of a change in the gasoline volatility on the fuel-consumption of cars now in service throughout the United States. Actual tests began in August, 1922, to determine the effect of four fuels of different characteristics on the number of car-miles obtainable per gallon of fuel, as well as on the crankcase-oil dilution. The earlier paper discussed tests run in summer time. The present paper treats those run under winter conditions. Observations also were made on an engine which was set-up and operated in the laboratory of the Bureau under test conditions.

Descriptions are given of the fuels used, the test-cars, the apparatus, the tests and the test methods. The paper also covers a continuation of the crankcase-oil-dilution investigation, with appropriate accompanying data. The results are discussed briefly.—[Printed in the July, 1923, issue of THE JOURNAL.]

WINTER TESTS SHOW LOWER MILEAGE WITH HEAVY FUELS

BY DR. H. C. DICKINSON AND JOHN A. C. WARNER

SINCE the road-service tests of the four special fuels supplied by the Research Department, made under 1922 summer-weather conditions, gave results that were deemed inconclusive, arrangements were made for a repetition of both series of tests under the winter-weather conditions of 1923 to determine whether the relative fuel mileages for different fuels are dependent on the temperature at which car operation is conducted. The paper is a report upon the results obtained.

Four fuels that bore a relation to those used in the 1922 summer tests were specified and means adopted whereby knowledge of their quality was concealed from the drivers, special emphasis being placed on crankcase dilution and on general performance as reflected by the drivers' comments. The method of test was, for the most part, that of the summer of 1922, with cars operated as usual by their regular drivers, the filling with fuel and oil and the keeping of records being wholly in charge of the technical staff of the company concerned.

The details of procedure are presented, together with voluminous tabular data, and comment is made. A consistent and important decrease in mileage for the winter tests is apparent. The conclusions reached are stated in detail, as a summary, under six divisions.—[Printed in the July, 1923, issue of THE JOURNAL.]

SPARK-ADVANCE IN INTERNAL-COMBUSTION ENGINES

BY G. B. UPTON

ALTHOUGH the proper timing of the spark is as essential as the spark itself and the electrical and mechanical devices for producing the spark have been many, little attention has been given to the study of spark-advance. An error in timing of ± 20 deg. in a low-compression engine, or of ± 15 deg. in most other engines, has been shown experimentally to cause a loss of 10 per cent from the best power and economy, provided other conditions remained the same. Hand or semi-automatic control can average hardly closer than ± 15 deg. to the correct advance because the speed and the load combinations are constantly changing on the road.

Two important phases mark the spark-advance problem. The practical question as to whether the requirements of optimum spark-advance at various combinations of load and speed are such as might be controlled automatically is apparently answered affirmatively; it can be satisfactorily represented by additive functions, one of speed only and one of load or intake-suction only. Hand adjustment would still be needed to take care of the difference between a clean engine and a

dirty one or of a cold engine. When once an engine has been warmed up, however, automatic controls could maintain the proper spark-advance, thereby increasing in practice the power, flexibility and economy of the engine.

The second phase is that of scientific analysis. Inasmuch as combustion takes time, and as the engine is rotating during the combustion process, spark-advance is essential, for it maintains a definite relation between the progress of the explosion and the motion of the piston of the engine. This relation should be such that half the rise of pressure during combustion would occur at the dead-center position of the piston. Analysis, however, both theoretical and experimental, shows that one-half of the pressure rise occurs substantially at three-fourths of the explosion-time, that is, the interval between the point of ignition and the pressure peak. This, then, is the numerical basis for the relations of explosion-time, engine speed and optimum spark-advance.

The existing data, relating to the explosion-time as affected by the mixture-ratio, the size of the combustion-chamber, turbulence, dilution with dead or exhaust gases and the temperatures preceding the explosion, are reviewed. Density is shown not to affect the explosion-time. The factor commonly supposed to be density, which demands an increased spark-advance as the engine is throttled, is in reality dilution with exhaust gas, which increases as the throttle closes, and the cause of the faster explosion in a high-compression engine than in one of low compression is the temperature preceding ignition.

A simple mathematical law, connecting the explosion-rate and turbulence and derived from experiments on bombs, is shown to be applicable to engines, and the manner of its application to the turbulence factor of any engine is indicated. This opens the way to quantitative experiments on turbulence in various designs of engine, hence to the development of designs for producing the greatest amount of turbulence, if such development should seem desirable, as turbulence is the factor that makes really high rotative speeds compatible with a good power output. An equally important factor in making explosions in engines occur more quickly than those in bombs is the heat produced adiabatically during the compression stroke.

The slowing-up of combustion on account of the dilution of the charge with exhaust gas was measured experimentally, and the results are tabulated and compared with the numerical extent of the dilution. Assuming that the dilution ratio is the ratio of the total charge to the quantity of new gas, the slowing-up of combustion because of dilution is demonstrated experimentally to be about proportional to the cube of the mass-dilution ratio.

The scientifically valuable part of the paper is the naming of the factors that affect the explosion-time of an engine, the giving of mathematical expressions for their laws of action and the finding of the numerical values of constants for such factors as turbulence and dilution. The measurement of the optimum spark-advance is made available as a research method for investigating the reaction rates of combustion, and hence of all that related group of topics now of interest to automotive engineers.

By measuring the optimum spark-advance, the combustion rates of gasoline with and without "anti-knock," or tetraethyl-lead, were measured. Although the quantity used was 20 times the normal amount, no change in the reaction rate of combustion was found when the combustion remained normal, that is, without detonation. When detonation occurred without anti-knock, the reaction times with anti-knock followed those to be expected with normal combustion. Detonation apparently changed the combustion habit as if it produced an abnormal top to the combustion.—[Printed in the August, 1923, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN CRANE:—Carded as a fuel and engine session, this meeting is simply another in the long series that we have found to be desirable to enable the members of the Society to keep abreast of the work that is being done constantly on the utilization of fuel. One of the principal activities of the Research Committee and of the Research Department has been the cooperative fuel investigation that has been carried on at the Bureau of Standards for the Society, the American Petroleum Institute and the National Automobile Chamber of Commerce. Through the courtesy of some of the large automobile companies in Detroit, the Society has been able in addition to make other research on a large number of cars. Although the tests have been different, the results of both series are extremely interesting. After listening to Mr. Lee's summary of the work done at the Bureau of Standards, we all realize that there is an immense amount of information to digest. Road tests, as they were conducted at first, were very limited in scope. The Steering Committee had to be educated as to the exact nature of the research work and the tendency was to place too narrow limits on the experiments to be made. As the work progressed, however, the scope has been widened until, during the last 6 months, the Bureau has had an opportunity to begin a search for fundamental facts regarding the amount of variation and, more important still, the cause of the variation in the fuel consumption, or the fuel performance, in fuels of different volatility.

I think it is impossible for anyone who listens to Mr. Lee's paper for the first time to begin to appreciate what there is in it. It is worthy of the most careful consideration by everyone who has anything to do with the design of carbureters, manifolds or engines. I hope that everyone who is interested in this matter will read the paper carefully, examine all the facts and then transmit to the Research Department any questions or suggestions that will aid in clarifying this important subject.

Referring to Dr. Dickinson's paper, I call attention to the point of view of the driver as to the quality of the fuel he thought he was using and what he actually was using. It is a very disturbing thing to me that by giving a driver a low initial point, or considerable volatility below the 20-per cent point, he can be "kidded" into using a fuel with a very high end-point without noticing the difference. Whether the driver may or may not have noticed the difference, the engine "noticed" it. Mileage per gallon and dilution both varied with the high end-point, although the driver thought he was getting a good fuel. In fact, the "square" fuel was not picked out by the drivers as being good, although it is a considerably better fuel.

Proper handling of the ignition has an immense effect on the satisfactory operation of an automobile and on the economy of the fuel used. Just how we can take care of the automatic features that are necessary to circumvent the usually dumb driver's method of handling, I do not know. The driver's handling of the car depends of course upon the locality in which he is using the car. If he is in a congested area where a great amount of acceleration is required, he is likely to leave the spark-advance at the point at which he can accelerate satisfactorily without undue knocking. He will leave it there even when the car is running with a very high inlet-suction. When he does so he obtains, of course, a much

lower mileage than he should obtain from the gasoline. On the other hand, we have the condition that, with the modern fuel, almost all carbureters tend to "go hollow" on the initial pick-up. This hollowness in the carbureter, or leanness of the mixture, or slow combustion, is partly offset by spark-advance. A higher spark-advance can be carried without getting a knock when the car is first opened up than it can be afterward.

THOMAS MIDGLEY, JR.:—In reference to the last point that Professor Upton brought up, that the anti-knock material did not slow-up normal combustion, the curve he showed is fine for our advertising department; it does not take away any power and gives all the advantages of anti-knock material. Unfortunately, that condition does not seem to be wholly true. I do not understand why Professor Upton did not get a shade of difference, because, when an engine is heavily overdosed with anti-knock material, there is a slight decrease in the power that is caused apparently by the slowing-down of the combustion. It is not great. It has been confirmed two or three times on the track. Top speeds are not so high when large amounts of anti-knock material are used as when they are not used.

I am frank to admit that we have not made any accurate spark-advance determination such as Professor Upton describes. He states that he used 20 times the usual quantity of anti-knock material. He told me he used 5 cc. per gal. That is just a little more than we are selling to the public and is not what we consider a heavy overdose. Another thing entering there is that the effect is logarithmic. The anti-knock material must be multiplied nearly four times to give twice the effect. I believe that five times the amount would not make a difference in the operation that could be detected readily by the spark-advance. I shall try to take some indicator-cards bearing on this point to get the actual pressure-rise of a perfectly normal engine having no tendency to detonate; for, of course, each engine is an individual. I shall average the results to see if we can detect any difference from or can confirm Professor Upton's results.

O. C. BERRY:—We are familiar with the very hasty perspective survey that an engineer will make of a situation, how he will draw a few conclusions and go ahead and act on them. It is always gratifying when a man with a scientific turn of mind makes a careful survey of the field, evaluates each little item carefully and confirms those conclusions. I feel very much gratified to find that some conclusions I drew a few years ago have been verified.

An apparatus was designed, put on an engine and tested. We found that an increase of about 3 miles per gal. could be obtained under average conditions. I selected a number of men whom I considered to be the best automotive engineers in that section. I watched them drive their cars. I was surprised to find that most of them, even in flat districts, set the spark so that the engine would not detonate when the car was accelerating rapidly from low speed; that is, where the least spark-advance could be used. Then they drove at 35 m.p.h. on a level road with that spark-setting. If one will set the spark like that, taking an average car and observing the number of miles per gallon, then put the spark where it should be and run the same car over the same road, he will find that he will get an increase of about 3 miles per gal. That will make it worthwhile to use an apparatus of this kind.

So, we attacked the problem again, trying to develop a device that would be sufficiently positive and foolproof, something so good that an automotive engineer would not find fault with it and would be willing to put it on cars of his own production. To our surprise, we found that the weak element in the whole thing was the centrifugal advance that we have been using for so long. To show what the trouble was, if one will make a careful study of what the centrifugal advance is doing and draw a curve based on the speed and the degree of spark-advance, he will find that it will come down and then come up on the regular curve when he runs at full load and low speed. If the jump occurred at high speed, one would not notice it much, but at low speed it introduces rather large irregularities in the performance. We had difficulty in finding apparatus that would get rid of the hunting at the lower end of the curve. I am pleased to say that a manufacturer, who became interested in the problem and worked with us, finally succeeded in turning out something that was entirely satisfactory. He made the curve run straight down to the bottom.

We combine that with a sylphon element, which is simply a brass cylinder arranged so that it can expand and contract, put a steel spring inside it and a linkage, and let the suction from the intake-manifold go in through a small hole. This makes a strong engine that has no tendency to strike or hang up and that gives a motion which is directly proportioned to the suction in the intake-manifold. The linkage connects the intake-manifold with the regular distributor head and there is fine compensation for speed and for suction. One of these pieces of apparatus was installed on an engine about 2 years ago. It has been in daily use in a car, has given no more trouble during that time than the front axle and seems to be foolproof.

The sad part, though, is the patent situation. According to the patent laws in this Country, if a man gets an idea that has any utility at all, even if it is only a partial idea, he can get a patent on it. One man noted one phase of the automatic spark-advance problem, a second man another phase and a third man a third phase, and they took out three separate patents. I think it would be impossible to develop any of those ideas separately and work it into a usable automatic spark-advance; together, they would work well, but no one man controls all the patents. As a final word, before anyone uses an automatic spark-advance of this kind, he should make a careful survey of the patent situation. I am not sure that the work I was interested in ever will result in a patent, but the apparatus that was developed there is thoroughly workable. If any one is interested, I shall be glad to explain it in detail. If I do get a patent, it will not stand in the way of any man who is getting out a good ignition system. I am not an ignition man. This is only a sort of sideline that we became interested in.

S. W. SPARROW:—One of the interesting facts pointed out by Professor Upton is the slow rate of the initial burning. This fact must not be overlooked in adopting any automatic device for advancing the spark, or in estimating the rate of combustion in an engine from the spark-advance at which the maximum power is obtained.

The initial burning is to some extent analogous to the burning of the fuse of a firecracker in that the quantity of material burned is extremely small, although the time consumed in burning this small amount is a large proportion of the total. Some engines require a much greater spark-advance than others and yet show no lower efficiency. The probable explanation is that in both engines the bulk of the charge is burned at nearly the same point in the cycle and in nearly the same time, although the initial period of burning of one is much longer than that of the other. If the firecracker just mentioned furnished

power for the engine, it is evident that doubling the fuse length would double the total time of combustion. The engine power, however, would not be affected appreciably by such a change, provided the firecracker proper burned at the same point in the cycle and in essentially the same time as before.

It seems, therefore, that we should use caution in assuming that the spark-advance in degrees before the top center represents three-quarters or any other definite proportion of the total time of burning. The possibility is too great that some minor change in the combustion-chamber design may considerably alter the total time of combustion, without changing appreciably the point in the cycle where the major portion of the burning takes place. I know of a case in which the screwing of a short length of pipe into the spark-plug hole and then putting the spark-plug in the end of this pipe increased the spark-advance required very much but did not change the power or the specific fuel-consumption appreciably.

PROF. R. E. WILSON:—Regarding the effect of dilution with exhaust gases on the rate of explosion, the data for which were derived experimentally as I understand it, might not the observed effect be due merely to the change in the pressure at the time the combustion began? In other words, the pressure, at the time of ignition is, of course, not the same with intake-manifold suction as without it, and therefore one would expect the initial rate of flame propagation to be different and in the same direction as it was found to be; that is, the flame velocities at low throttle-openings corresponding to high dilutions would be lower. How much of the observed effect was due to dilution and how much to pressure?

A second point on which I am not clear relates to the method by which the curves in Fig. 6 of Mr. Upton's were obtained. One curve for flame velocity shows a constant velocity throughout the time of burn; was a constant velocity the assumption on which the curves were derived, or just what is the significance of the figure?

PROF. G. B. UPTON:—Regarding the effect of the change of pressure, the explosion-time is entirely independent of the initial pressure or the density of the gases; it has nothing to do with them at all. Laboratory experiments have covered pressure ranges preceding ignition of the order of 75 to 1; from atmospheric pressure to a pressure of 1100 lb. per sq. in. The time of combustion is independent of the initial pressure, at least within that range, which is very much wider than the range covered by throttling the engine. The thing that we have been calling a pressure effect in the cylinder is dilution. It is not pressure at all.

As to Fig. 6, I made an initial assumption that the flame velocity is variable and that it varies in direct proportion to the time from ignition, starting at zero and increasing in direct proportion to the time. That assumption is not true, but it is a sufficiently close approximation so that a geometrical case can be worked out and our ideas shaped as to what happens.

CHAIRMAN CRANE:—During the last 2 years we have been running tests on an engine of the overhead-valve type having a 4 to 1 compression-ratio and a rather early inlet-valve closing, which gives probably the maximum actual compression for that ratio. We have tried the engine with both single and double ignition. It has a perfectly cylindrical combustion-chamber, with diametrically opposite spark-plugs when double ignition is used, and with a spark-plug on the side for single ignition. With single ignition and at say 1200 r.p.m. at full throttle, a spark-advance of approximately 60 deg. was required. With two spark-plugs, a spark-advance of about 35 deg. will give the same result; in other words, that is the optimum advance in each case. It also represents equal power in each case as nearly as we could measure it with ordinary brake equipment. It is obvious, however, that the pressure in the cylinder when ignition is started is considerably greater in one case than it is in the other. I would be much interested to see what effect the pressure at the time of ignition has on the explosion time.

HERBERT CHASE:—As I understand it, Professor Upton defined the explosion-time as the time from the passage of the spark to the completion of the combustion. He speaks of the completion of the combustion as coming very close to the top of the card. Unless our eyes deceive us, we know, by observing almost any engine running without an exhaust-manifold, that the combustion is seldom entirely complete, even when the exhaust-valve opens which, of course, is comparatively near the end of the stroke. Just what does Professor Upton mean by the completion of the combustion; does he mean that the combustion is actually complete or nearly complete at the top of the card under all conditions?

PROFESSOR UPTON:—The case of spark-advance cited by Chairman Crane is geometrically interesting. If the two spark-plugs were symmetrically placed and cut the flame travel approximately in two, the expected change of combustion time would be as the $\sqrt{2}$ which would change the spark-advance of 60 deg. to about 32 deg.; he said it was 35 deg. Apparently, he gives another check on what I said was the empirical law of the effect of the distance of the flame travel. The explosion-time is cut in proportion to the square root of the distance of the flame travel.

CHAIRMAN CRANE:—The point that I wished to be considered was that, in one case, the start is under entirely different pressure conditions from those in the other case.

PROFESSOR UPTON:—Earlier in the compression stroke.

CHAIRMAN CRANE:—And at a distinctly lower compression.

PROFESSOR UPTON:—Yes. It must be far enough away from dead-center; 60 deg. would be rather far. The start is in the early stages of the flame travel when it has not done much, and the rate of the combustion must be fixed more toward the end where it counts most. Of course, the spark-advance must be affected by the lower initial compression. The reason is that the rise of the temperature during compression has not reached so high a stage at the time of early spark-advance as it would reach with a later spark. The temperature produced by adiabatic compression is an important factor in the spark-advance. The higher the compression-ratio is, the higher the temperature preceding the ignition is and the more rapid the combustion will be.

I think Mr. Chase's eye deceived him. When an engine is running at full load and high speed the exhaust-pipe is at a red heat. The gases are hot enough to be red-hot and to make the exhaust pipe so. They would begin to be red-hot at about 1000 deg. fahr., and the exhaust temperatures would rise to 1600 and 1800 deg. fahr. with full-power operation of the engine, so that the thing ought to look red-hot.

One can see when the end of the combustion occurs by a spectroscopic examination through a window in the combustion-chamber. The end occurs slightly after the pressure-peak. The reason is that, in the chemistry of the combustion, neither hydrogen nor carbon can burn completely at the higher temperatures at the top of the combustion. H_2O and CO_2 must be dissociated partly at the extremely high temperatures and they cannot com-

bine completely until expansion has lowered the temperature in the cylinder. Consequently, there is some chemical action occurring after the pressure peak. We cannot help it. It is purely a matter of physical chemistry.

MR. CHASE:—It may be that my eyes deceived me, but I have seen many engines running without an exhaust-pipe with the flame from the exhaust port burning as far as 1 ft. from the engine. It may be that gas at that temperature is visible when it is not burning, but I doubt that such is the case. If it is visible, perhaps my conclusions are wrong, but I still think that oftentimes the gas coming from the exhaust of an engine is still burning when it leaves the port. If by "complete combustion" the using up of all the oxygen in the cylinder is meant, this may well occur in some cases at or near the top center, but after burning often takes place when the exhaust-valve opens. There is no doubt about it and I believe Professor Upton will grant that I am correct in this.

PROFESSOR UPTON:—Possibly; with a rich mixture, it would continue to burn.

A. J. SCAIFE:—Would the early opening of the exhaust-valve have some effect on that?

PROFESSOR UPTON:—I cannot say that it would have much effect. If the gases were held in longer with a later exhaust-valve opening, they would cool a little before they were turned loose but it would not make much difference. I am inclined to think that a visible flame from an open port means a rich mixture and that combustion is still going on. A yellow gas would mean that the carbon part was still unburned.

PROFESSOR WILSON:—Professor Upton's observation that the pressure makes no difference in the time required for the explosion is, of course, very interesting and an important one. I wonder just how it can be reconciled with Mr. Midgley's interesting observations in which he showed that the speed of the flame travel is proportional to some power of the absolute temperature and to the density of the charges? Some equations were worked out which gave a very real value for the exponent n, under conditions such that dilution could not account for the result; in other words, it was taking care of the change of the pressure as the explosion was going on. Professor Upton's experiments would appear to indicate that n was zero.

MR. MIDGLEY:—The value of n that we have, treating it in that particular way, is 0.9. The value found by treating it in another way was 1.1. The space velocity of the flame would be the same, because there would be twice as much gas and twice as much burning, thus requiring the same time. If the value of n is 1.0, everything checks perfectly.

R. W. A. BREWER:—The data that have been presented are so comprehensive that it is not possible to say much, except to ask for a little more information on one or two points. I think we should have an exhaust-gas analysis of the two fuels that were dealt with in Mr. Lee's paper because, from the information which depends on the opening of the fuel needle, it is impossible to say exactly what is happening in the combustion process. It would appear that opening the fuel needle wider for the less-volatile fuels would lead to a combustion efficiency that was rather low, but we have no such indication thus far, and I think we should have. We might get it from an exhaust-gas analysis or from a carbureter-characteristic curve. If such a curve were included, it would add very much to the value of the paper.

CHAIRMAN CRANE:—You will find the carbureter-characteristic curve in the complete report.

MR. BREWER:—In that type of carbureter the characteristic is peculiar. Was it a Kingston carbureter?

STEPHEN M. LEE:—A Kingston L-4 carbureter was used.

MR. BREWER:—It has very curious methods of "riching" and "leaning" the mixture according to the speed of the engine, and not in straight-line curves.

CHAIRMAN CRANE:—Those curves have already been made and published.

MR. BREWER:—Do they give information as to how much or what percentage of the combustion has been used efficiently? It is conceivable that although the needle may have been opened more for the least-volatile fuel, that fuel may not have been burned at all. It probably has been burned partly; it seems likely that much of it has been discharged into the exhaust, and this fact might account for the flames that Mr. Chase mentioned. All kinds of compounds may be forming in the exhaust that we have attributed to something which may not exist.

CHAIRMAN CRANE:—The Bureau of Standards is trying to cover all these points. Mr. Lee will tell us what information is to be published.

MR. LEE:—If two fuels such as B and D are used under conditions such that there is no difference in the fuel consumption per horsepower-hour and no difference in the power output, it is evident that the fuel flow was the same in each case. Any difference in needle-valve opening would then seem to be due to a difference in the fuel viscosity. There is a difference in the viscosity of about 10 per cent between the fuels.

In comparing the two fuels, the characteristics of this particular carbureter did not seem to me to be of sufficient interest to be put into this report. However, they were included in the progress reports that were sent to members of the Steering Committee.

CHAIRMAN CRANE:—I think it is desirable that all such information should be published for the benefit of all the members of the Society. The Steering Committee is not trying to keep anything secret; in fact, the more widely these data can be published and the more they can be thought about and commented on, the better the Steering Committee will like it. We cannot begin to reach all the possibilities. Mr. Lee showed me other curves of those temperatures that I think ought to be and I hope will be published. They are not exhaust-gas analyses but are the exhaust temperatures taken from the individual cylinders. They gave some interesting information on the very faulty distribution that is known to exist in this particular engine.

MR. BREWER:—Could we have a few examples of exhaust-gas analysis in the final report?

CHAIRMAN CRANE:—I hope we shall have them because I think they are desirable.

MR. BREWER:—Especially if they could be taken from separate valves on the same engine.

CHAIRMAN CRANE:—We can try to do that.

W. S. JAMES:—One point that should be taken into consideration is the burning of the oil. An exhaust-gas analysis will include not only the products of the combustion of the fuel, but also the products of the combustion of the oil. The distribution of the oil may be poor and, for the study of distribution, an analysis of the exhaust gases alone may give confusing results.

CHAIRMAN CRANE:—Mr. Brewer's idea is one that I hold; that it is just as well to make a few analyses to see whether they indicate anything. I agree with Mr. Lee that there should not be any noticeable difference in the use of the fuel as indicated by the power-measuring appa-

ratus; the apparatus for measuring the amount of fuel used is apparently the same in both cases. There should not be very much difference in the gases coming from the exhaust pipe, but if the information were available it might show something.

MR. BREWER:—In view of the low temperatures at which these tests have been made and the notoriously faulty distribution, I think it would be unwise to jump to a general conclusion that, because certain adjustments have been made, the results of the combustion are at all comparable. They may not be comparable. The final results may be more or less comparable, but the individual processes may be entirely different without confirming the conclusions that might be drawn from a very much more detailed examination, if that could be had.

CHAIRMAN CRANE:—As I have explained, when we started out this whole investigation was rather restricted in scope. To begin with, the Bureau of Standards had a limited amount of money to spend, and only gradually could the scope be widened so that the investigation can be conducted on really broad lines, as it should be. Originally, we tried to find out whether there was any difference between the fuels in the mileage to be obtained per gallon of gasoline. That was about all we were allowed to attempt. Even if we found that the mileages were different, we were not supposed to know very much as to the reasons, but only that the fuels were different. We are now trying to find out where such differences are most likely to occur, and when those points have been discovered to find out why they occur at those points.

We ourselves may be vulnerable. We know we are vulnerable when we design carbureters that have a very serious viscosity factor. We are working with something that is evidently bad for us on account of the wide variety of fuels we must use and the wide variety of temperatures that we encounter. On the subject of viscosity, we start with a cold engine and we need a rich mixture anyway, but we finish with a hot engine. I suggested to the oil companies that if they could give us gasoline of low viscosity when it was cold and of high viscosity when it was hot, we would appreciate it greatly.

C. H. KINDL:—We should not lose sight of the fact that although we might take into consideration the throttle effect in the designing of a mechanism that combines both the speed and the throttle opening for a particular engine, yet we cannot combine in that design features which will take care of the engine after it has operated for 5000 miles. Variations in compression, fuel ratios and carbon in the cylinder, affect the proper optimum advance so that the delicate adjustments that were made primarily are almost useless and, for that reason, a lever on the quadrant of the steering-gear must be provided so that the operator can adjust the spark-advance to take care of the condition of the engine.

Although we may provide a very intricate mechanism to give the maximum economy, we still must put the whole operation into the hands of the driver to take care of conditions that will change as the engine becomes older. In that light, the expense and complications seem almost useless if the operation cannot be taken out of the hands of the driver entirely.

C. B. DICKSEE:—Some tests made by the Westinghouse Electric & Mfg. Co. to determine the effect of a change in the mixture-strength on the optimum spark-advance are of interest. These tests were made on a Westinghouse single-cylinder E-60 air-cooled engine, having a 3⅜-in. bore and a 5-in. stroke, and a compression-ratio of 4 to 1 at the time of the test. The combustion-chamber was cylindrical, the spark-plug passing through the side of the cylinder at right angles to the diameter on which the valves lie. During some experiments to determine the effects of the mixture on the cylinder temperature, it was noticed that a considerable variation in the spark-advance was necessary after a change in the mixture; therefore, a few tests were made to ascertain the relations between them.

During one series of tests, pressure-time cards were taken on a Midgley indicator so that the effect of the change on the combustion line could be observed and also with a view toward obtaining some idea of the time required to produce the maximum pressure after ignition. For this latter determination, some means of locating a point on the pressure-time diagram definitely is needed urgently. For want of anything more definite, several diagrams were taken with the ignition momentarily switched off, the top dead-center position being obtained by drawing a line parallel to the atmospheric line about half-way up the diagram. A point half-way between the points of intersection of this line with the compression and the expansion lines was taken at the top dead-center. One of these curves was transferred carefully to a piece of thin celluloid that was graduated in 5-deg. divisions on each side of the top dead-center. To use this instrument, the atmospheric lines of the instrument and of the diagram were made to coincide, and the celluloid was slid along until the compression lines coincided also. It was easy then to determine with fair accuracy the top dead-center and mark off the ignition-point, which was obtained by a rotary spark-gap. This method is open to obvious objections but, as the indicator is now built, no more direct or accurate method seems to be available. The spark position was obtained by advancing by steps till a further slight advance produced no change in the speed. This method is not to be compared with that of taking readings at different settings and obtaining the optimum from a curve of results, but the results described here are a preliminary to work that it is hoped to carry out in more detail in the near future.

In all, three sets of readings were taken. In two of the sets the spark position was adjusted as described and, during one of them, pressure-time diagrams were taken. In the third set the spark was kept constant at the advance called for by the chemically correct mixture and pressure-time diagrams were taken. The mixture was

TABLE 3—RESULTS OF TESTS WITH VARIABLE SPARK-ADVANCE

Run No.	407	408	409	410	411	412	413	414	415	416	417	418	419
Speed, r.p.m.	1,260	1,250	1,260	1,250	1,260	1,240	1,240	1,250	1,260	1,250	1,265	1,250	1,255
Power Developed, b.hp.	5.90	5.97	6.00	5.82	5.71	5.24	5.04	4.66	6.06	5.85	5.61	5.24	5.45
Fuel Consumption, lb. per b.hp-hr.	0.956	0.826	0.755	0.677	0.652	0.631	0.575	0.606	0.700	0.644	0.638	0.625	0.587
Mixture-Strength	12.0	12.5	13.1	14.4	15.1	16.3	18.1	19.3	13.4	14.5	15.6	16.8	16.8
Spark-Advance, deg.	27	27	26	21	25	31	45	61	30	27	24	24	35
Time to Reach Maximum Pressure, sec.	..	..	..	..	..	..	..	..	0.0049	0.0044	0.0041	0.0095	0.0063

TABLE 4—RESULTS OF TESTS WITH A CONSTANT SPARK-ADVANCE

Run	Mixture-Strength	Spark-Advance, Deg.	Time to Reach Maximum Pressure, Sec.
A	13.6	23	0.0058
B	14.2	23	0.0036
C	15.1	23	0.0036
D	15.9	23	0.0051
E	17.2	23	0.0090

determined from exhaust-gas analysis converted by Lockwood's formulas.[2] All readings are at full throttle, the speed being maintained as near 1250 r.p.m. as possible. This means that the crank passes through an angle of 7 deg. 30 min. in each 0.001 sec. and facilitates the taking of time measurements from the diagrams. The results of the experiments are given in Tables 3 and 4. Table 3 gives results of the test in which the ignition-point was adjusted to suit each condition. In Table 4, the spark-advance was maintained constant.

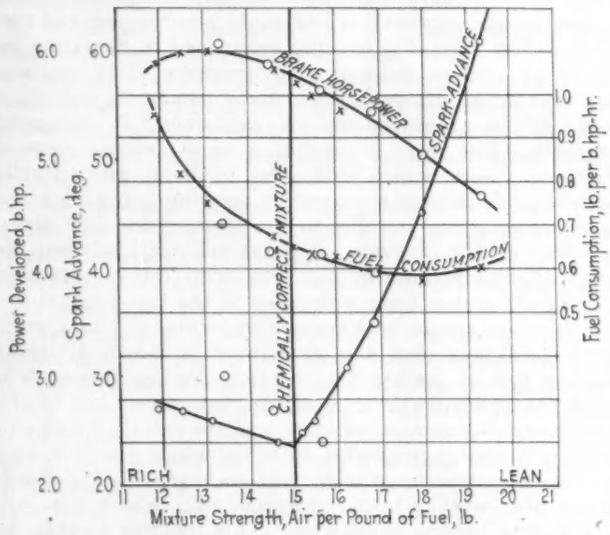


FIG. 10—CURVES SHOWING THE SPARK-ADVANCE THAT IS REQUIRED WITH VARIOUS MIXTURES AND THE RESULTING FUEL CONSUMPTION AND BRAKE HORSEPOWER

The results of the tests are shown also in the accompanying curves. Fig. 10 indicates the spark-advance necessary for various mixtures and the resulting fuel consumption and brake horsepower. Fig. 11 shows the time to reach the maximum pressure plotted against the mixture strength, both when the spark-advance is varied and when it is kept constant.

It will be seen from Fig. 10 that the spark-advance required for a given mixture-strength does not agree wholly with that given in Fig. 1 of Professor Upton's paper. Our experiments gave a minimum advance when the mixture was chemically correct; that is, 15 lb. of air per pound of gasoline. This is rather what one would expect as, under these conditions, the dilution is a minimum and consists solely of residual exhaust products. There are material differences between the two engines upon which the tests were run, one being air cooled and having a cylindrical combustion-chamber, the other being a water-cooled machine with the valves at the side that produce a combustion-chamber that is shaped very differently. The compression-ratio of the two engines probably is different also. The hotter cylinder of the air-

[2] See THE JOURNAL, March, 1923, p. 299.

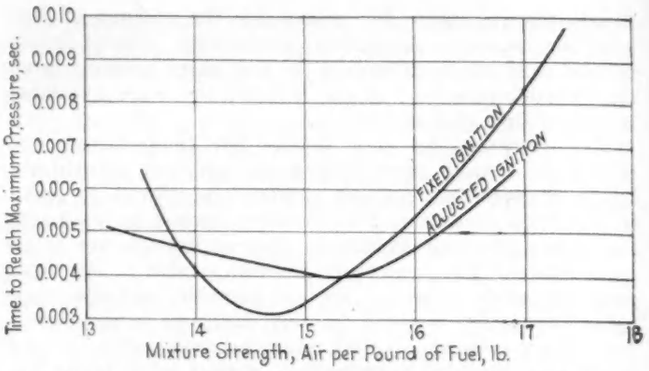


FIG. 11—CURVES IN WHICH THE TIME TO REACH THE MAXIMUM PRESSURE HAS BEEN PLOTTED AGAINST THE MIXTURE-STRENGTH FOR A VARIABLE AND A CONSTANT SPARK-ADVANCE

cooled engine together with the more compact form of combustion-chamber undoubtedly will tend to increase the rate of flame propagation and thus reduce the advance necessary; and also it may influence the mixture at which the maximum propagation is produced.

The shapes of the two curves also differ somewhat in that the rate of change of ignition with the mixture-strength is less for rich mixtures and greater for lean mixtures, according to our test; and, with the 15 to 1 mixture, a sudden change in direction appears that produces two distinct curves instead of the one continuous curve derived from Professor Upton's experiments. These differences probably are attributable to the difference between the two engines, and a comparison of the results given by widely different engines should help to elucidate the influence of the differences of design on the advance necessary and on combustion problems.

The two curves shown in Fig. 11 do not agree fully, as the time to reach the maximum pressure should be the same for both curves with a mixture in the neighborhood of 15 to 1. With the limited number of diagrams available, however, an absolute agreement could not be expected but, by averaging a larger number of diagrams, a much closer agreement should be obtainable. The curves do, however, give a general idea of what can be expected.

A point well worth noticing is shown in runs Nos. 418 and 419. In run No. 418, with an angle of advance of 24 deg., the time required to produce the maximum pressure was 0.0095 sec. Under exactly similar conditions

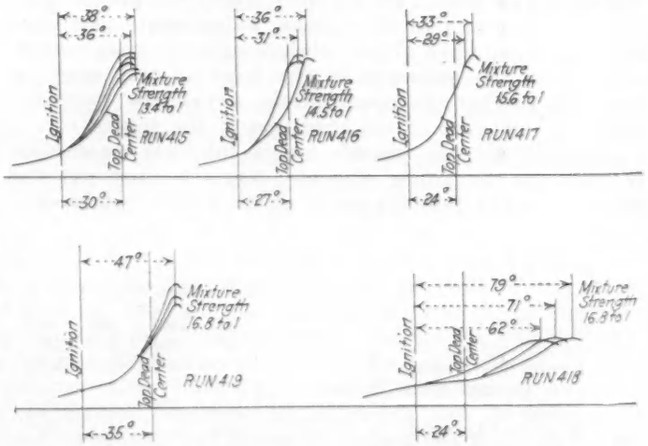


FIG. 12—DIAGRAMS SHOWING HOW THE TIME REQUIRED TO REACH THE MAXIMUM PRESSURE WITH A GIVEN MIXTURE VARIES WITH THE SPARK-ADVANCE

but with the spark advanced 35 deg., the time to produce the maximum pressure fell to 0.0063 sec. This indicates that the time required to produce the maximum pressure with a given mixture varies with the spark-advance. This is clearly shown in Fig. 12, which gives the combustion line from the pressure-time diagrams of runs Nos. 415 to 419, the difference between the combustion line for Nos. 418 and 419 being very marked. A further investigation of this point would form an interesting study and might throw light on the phenomena of combustion in a closed cylinder.

As already indicated, these tests were of a preliminary nature and it is hoped to go further into the matter at an early date. The figures for time obviously cannot be considered as other than approximate, on account of the method necessary for locating a point on the pressure-time diagrams. A similar investigation carried out on a slow-speed engine, using an ordinary indicator but with the drum rotated by a positive drive from the crankshaft, would supply some very valuable information.

PROFESSOR UPTON:—Mr. Dicksee raises three points; (*a*) that the curve of the optimum spark-advance versus the mixture-ratio, other conditions remaining unchanged, is perhaps two-branched, the branches joining at the theoretical 15 to 1 ratio; (*b*) that the time of the half-pressure rise is highly variable from the value of 0.75 of total combustion time, given as good in my paper and (*c*) that the time of combustion is itself variable with the spark-advance and is shorter with the greater advances.

The weight of evidence is against the idea (*a*) that this curve is two-branched. Figs. 1 and 2 of my paper show that, in the bomb experiments, the curves of the combustion-time versus the mixture-ratio are single curves. We have taken many curves in our own engine work, such as those of Fig. 3, and all are of the type of Fig. 3. We estimate the accuracy of the hand setting for the optimum advance by watching the dynamometer, at about ± 5 deg. If Mr. Dicksee will apply this probable error to the points with which his curve is plotted, he probably will concede that his curve need not be two-branched.

As to (*b*), I have summarized in Tables 1 and 2 of my paper the type of our results with indicators, taking pressure-time curves on a low-speed engine. The range of variation of the factor is 0.65 to 0.85 for individual observations and 0.71 to 0.81 for averaged groups. The factor seems to depend on the mixture-ratio, being greater for lean mixtures. We have no indicator-cards of our own from speeds above 1000 r.p.m.; but the cards published by Judge[3] fall in this same range of values. The value 0.75 was suggested only as a fair average.

In regard to (*c*), Table 1 of my paper shows perhaps the same tendency as is noted by Mr. Dicksee, though in a much less degree. It shows in our data only on lean mixtures. One might expect the combustion to be somewhat quicker with an earlier spark, because the turbulence is then greater, especially in a valve-in-head engine. But this turbulence effect might be overcome by the fact that the compression-ratio, during the early stages of combustion, is lower with an early spark than with a later one. This phase of the problem is complex and probably very much a matter of the individual engine.

[3] See High-Speed Internal-Combustion Engines, by Arthur W. Judge.

WIRE WHEELS

(*Concluded from p.* 204)

precision fit. The method of machining the driving flange is somewhat novel, although it has been known to many who are familiar with lathe backing-off attachments that are used for making form milling-cutters, hobs and the like. The mechanism for machining the hub corrugations is a specially developed engine-lathe, driven by gears of the correct ratio to produce the required number of in-and-out motions of the tool-slide, which is connected to an eccentric shaft of a certain throw corresponding to the depth of the corrugation required. The taper is obtained by setting the tool-slide at an angle with the corresponding hub-shell driven member, which in turn is made equally accurate on a coining press.

The positive locking hub-cap shown in Fig. 5 consists of two principal members, the inner member, known as a corrugated sliding barrel fitting into similar corrugations in the outer member or hub-cap proper. This sliding barrel is held under tension by four springs, having approximately 15-lb. pressure per spring, and the barrel in operation having a movement of approximately $\frac{3}{8}$ in. The barrel is operated by a special wrench with a puller and cam lever so that the full travel of the barrel is obtained by moving the lever through 180 deg.

In assembling the cap to the hub, it is necessary first to withdraw the sliding barrel by using the wrench and its attachments; the hub-cap then is screwed into place and the sliding barrel is released. The wrench should then be tightened more and, upon reaching its proper position, the teeth on the inner end of the sliding barrel snap into mesh with the corresponding teeth on the hub itself, giving an absolutely positive engagement until the sliding barrel is again withdrawn.

Although we believe that the wire-spoke wheel is the best that can be made for automobiles at the present time, developments have often been brought about that have caused a reversal of what has seemed to be well founded experience; and it may be that, in the future, a wheel will be developed that will embody the good points of the wire wheel and perhaps have certain advantages over it. What kind of wheel this will be we do not know, but so far as our present knowledge goes, we believe that a steel wheel is, without question, better than a wood wheel, and that a wire wheel, properly built, is the logical wheel for an automobile, whether considered from the viewpoint of safety, strength, economy or appearance. [The discussion of this paper is printed on page 211.]

Rear Axles for Trucks

By E. FAVARY[1]

METROPOLITAN SECTION PAPER *Illustrated with* DRAWINGS

ON account of the pressure upon the space in recent issues of THE JOURNAL which made it necessary to withhold publication of the paper itself for several months, it was also necessary for a departure to be made from the usual practice of publishing a paper and the discussion following its presentation in the same issue of THE JOURNAL. This paper was published last month and the discussion following its presentation is given below. As is the custom, an abstract of the paper precedes the discussion so that those of the members who did not read the paper when it was printed in the August issue of THE JOURNAL can gather some knowledge of the subjects covered by reading the abstract if they do not wish to take the time to read the complete text.

ABSTRACT

THE five types of final drive now in use on motor vehicles are stated by the author to be (*a*) the chain-and-sprocket, (*b*) the bevel-gear, (*c*) the worm-gear, (*d*) the double-reduction and (*e*) the internal-gear. The advantages of each type as emphasized by its maker are presented and commented upon, and the same procedure is followed with reference to their disadvantages.

Following these comparisons of the different drives, which cover about the first third of the paper, the bearing loads and shaft stresses of typical semi-floating and full-floating axles are calculated for the conditions (*a*) maximum torque plus the normal radial load on the wheel, (*b*) the wheel locked and skidding forward when the brakes are applied and (*c*) the wheel skidding sidewise while the truck is moving. A tabulation of the results obtained from the mathematical calculations is included. The author concludes from these results that while the maximum shaft-stresses are practically the same in both designs, the shaft in the full-floating axle can be made lighter and that a higher factor of safety should be employed in the semi-floating axle since the bending stresses are continually reversed. As the bearing loads in the full-floating axle are considerably higher, a greater bending moment is imposed on the axle housing, thus increasing the production cost of this axle because of the necessity for heavier bearings and axle housing.

The last third of the paper is profusely illustrated with photographs and drawings of various types of rear axle. These include the rear axle of the Class B truck, as well as commercial examples of the worm drive, internal-gear-driven axles with load-carrying members of different sections, double-reduction axles and an example of a chain final-drive. [Printed in the August, 1923, issue of THE JOURNAL.]

THE DISCUSSION

CORNELIUS T. MYERS:—At the request of Chairman H. W. Slauson, I have reviewed the excellent display of truck rear-axle design given in Mr. Favary's paper, with respect to the possibilities for standardization. To attempt specific recommendations in detail calls for a complete and arduous study of the design of each type of axle and a careful comparison of points. Naturally, I have not had the time to make such a study.

A casual glance through Mr. Favary's paper by a member of the Society's Standards Committee will cause him to contemplate with awe the enormous investment in axle spare parts it must entail to service the different makes of motor truck already in operation. Further contemplation multiplies this by the amount of different manufacturing tool equipment necessary to produce them, and the terrific expense it must entail to keep the many little armies of salesmen each fighting their 20-sided battles over unimportant detail. I have enumerated 12 features of the various axle designs that seem to offer more or less attractive fields in which to pursue the well-defined and enormously profitable policy of standardization, that has been steadfastly fostered by the Society of Automotive Engineers. These are included in my paper Notes on Motor Trucks.[3]

The various types perform exactly similar functions in a variety of ways; (*a*) they support the springs on which rests the weight of the body and the pay load; (*b*) carry the brakes; (*c*) are supported by the wheel bearings; and (*d*) carry the parts that transmit the engine torque. For equal loads, stresses and similar points of attachment, it is natural to think that the same bearings and proportion and size of parts will serve as well on one axle as on another. In this light we can investigate the present subject by comparing the similar aspects of the various axles.

The range of truck sizes to-day can be divided roughly into seven categories as indicated by their pay-load capacities; namely, ¾, 1, 1½, 2½, 3½, 5 and 7½-ton sizes.

All types of rear axle are now so perfected and perform so well that a standardization of all assembly dimensions is the next important move in the progress of the industry.

O. M. BURKHARDT:—The duties of a rear axle are numerous. It must carry a large part of the chassis load and, in addition, a still larger part of the weight of the body and the useful load, transmit the engine power to the wheels and transmit the tractive effort or propulsive force. The containing casing must resist the torque due to the drive and, in the case where torque-rods are used, it must also resist the braking load. From this statement it is fairly evident that a clear picture of the proportions and stresses involved must be obtained before the final word can be said as to what type of axle is to be chosen for a particular type of vehicle. In this respect we are very much interested in Mr. Favary's intention of analyzing the stresses involved in different designs, such as semi-floating and full-floating axles, and wish that this analysis included the internal-gear, double-reduction and chain drives.

Concentrating first on a comparison between the semi-floating and the full-floating types of axle, we have within the Pierce-Arrow Motor Car Co. a number of specimens for direct comparison. For instance, we are using the

[1] M.S.A.E.—Consulting engineer, New York City.

[2] Copy for illustrations supplied by the McGraw-Hill Book Co., New York City.

[3] See THE JOURNAL, October, 1922, p. 333.

semi-floating type in all of our passenger cars and on the 2-ton trucks, and the full floating type of axle on our 3½ and 5-ton trucks. The reason for this is entirely a matter of calculation. For instance, to withstand properly the stresses of combined torque and bending, in the case of the 2-ton truck, our live-axle shafts work out to be of such size that no designer would care to go beyond it. The shaft approaches such dimensions that the effect of heat-treatment begins to be questionable, because it is evident that heat-treatment is most effective on thin sections. Hence, if we come to shafts of more than 2¾-in. diameter, the most desirable properties are not obtainable from the steel. In other words, the shaft diameter of our 2-ton truck seems to form a distinct line of demarkation as to how far one can go with the semi-floating axle. It is the simplest and cheapest design for vehicles of less than 12,000 lb. gross weight, but it is impractical for anything above this gross weight.

The full-floating type of axle is somewhat more expensive, but as it is possible to separate the bending stresses from the torque stresses with this type of design, we have a logical stepping-stone to another category of vehicle; namely, those above 12,000-lb. gross weight. The larger bending-stresses, due to the load of the vehicle, are taken by a large-diameter load-carrying tube, and the torque stresses are taken by a solid axle surrounded by the load-carrying tube. The calculations show that, for vehicles of more than 12,000-lb. gross weight, the load-carrying tube and the torque-transmitting axle are lighter than a single member taking both torque and bending. Further, we have a line of demarkation on the 2-ton model or 12,000-lb. vehicle with regard to radius and torque-rods. For instance, in our larger trucks we use radius and torque-rods because the stresses imposed on the springs due to torque reaction would be so great that the springs would need to be much stiffer without these members, to reduce the fiber stresses properly. In case of the 2-ton truck, we found that we were able, with the springs, to take care of the torque reaction without coming into excessive spring sizes. However, it cannot be denied that if a spring is designed stiff enough to take care of the torque reaction, the riding qualities of the vehicle are impaired. The springs are then stiffer than is necessary to carry the static load. In the case of the truck the riding qualities are not so important and, as price is of some consideration, this condition in which the springs take care of the torque reaction is tolerable; but in the case of the passenger car, in which the riding qualities are of supreme importance, a torque-rod must be introduced to relieve the springs of any other duty except that of supporting the load.

With regard to the other types of axle, the internal-gear axle is losing in favor because of the great difficulty of keeping the gears well lubricated, preventing oil leaking out to the brakes and securing a reasonable life for the gears. The internal-gear-drive axle is by far the simplest, lightest and cheapest; but, because of the disadvantages that have been mentioned, the axle is losing in favor.

The double-reduction axle occupies the extreme position, that diametrically opposite to the internal-gear axle. It is by far the heaviest, the most complicated, the costliest and the most difficult axle to repair and maintain in good condition. Therefore, the double-reduction axle has very few admirers or adherents at present.

The worm-drive axle occupies a position in between the two extremes. It is somewhat heavier than the internal-gear type but is lighter than the double-reduction axle. It is simplicity in itself; outside of the differential, only two gears are required. These gears, if properly designed, last almost as long as the truck. The lubrication is taken care of easily. It has proved continuously to be a highly efficient means of power transmission. It is silent in operation, lends itself to a symmetrical design of case and it makes for an axle that one can produce in quantity, which is a point of great importance.

There are satisfactory and unsatisfactory worm-gear axles. In my opinion the best practice is to mount worm gears on ball bearings throughout. It is preferable to anchor the worm shaft on one side of the shaft only, so that the shaft is free to expand without cramping itself. This expansion is a phenomenon that must be well taken care of in case the worm shaft is to be mounted in taper roller-bearings. For instance, if the worm unit increases 200 deg. fahr. in temperature and the length between the bearings is 15 in., we have a total expansion of about 0.020 in. The bearings must be protected against tightness; hence they should be fitted with not less than this amount of clearance at room temperature. By far the best practice is to mount the worm above the wheel. This is to obtain a practically straight-line drive from the gearbox. Lubrication is taken care of easily by providing little troughs in the worm housing. While dwelling on the subject of bearings, it can be emphasized that taper roller-bearings are extremely practical where end-thrusts are not excessive and where a slight end-play is tolerable, such as in the road wheels.

With regard to the design of the worm gear itself, we note from a paper by Kalman Heindlhofer, Tests on Rear-Axle Worm-Drives for Trucks,[4] that worm gears of the ordinary design are subject to failure unless they are made of the proper steel. Mr. Heindlhofer gives several illustrations of broken worm-shafts, and he correctly emphasizes that the failures were due to having made the worms of a straight carbon-steel, instead of from an alloy-steel. There has been an innovation in worm-gear design, emanating from England. The design that I have in mind is known as the FJ type of gear, the letters being the initials of the inventor, F. J. Bostock.

These FJ gears have proved to be extremely successful. The contact area between the teeth is truly symmetrical, instead of being one-sided. The area in contact in extreme cases is five times as great as in the ordinary worms of the involute type. The rubbing velocity is only about 30 per cent of what it is in ordinary worm-gears. This is because the relative motion is mostly a rolling one, instead of being wholly a sliding motion. In fact, the FJ type of gear is closely allied to the spiral-bevel gears. This decrease in sliding velocity and almost pure rolling velocity permits a considerable increase in load. It has been found that the torque capacity of these gears is 25 to 40 per cent greater than that of gears of the ordinary involute design. A peculiar inefficient characteristic of involute design is that the extremities of the lines of contact travel toward each other until they meet and vanish somewhere near the center of the gear. This explains the well-known fact that, when a wormgear of the involute type is overloaded, pitting first takes place on the outside of the wheel and on this side only, while those portions of teeth on the entering side of the wheel remain unmarked.

We have found the spur-gear type of differential su-

[4] See *Mechanical Engineering*, November, 1920, p. 613.

perior, because it is not subject to end-thrust and, while it has somewhat greater backlash than the bevel-gear type when new, it is subject to less wear and remains in its original condition almost forever; whereas the bevel-gear type of differential is hard to line-up, and wears quickly because of the presence of end-thrust.

After carefully studying Mr. Favary's paper, I find a few things that are not wholly in keeping with our experience. For instance, Mr. Favary finds that a semi-floating axle is most highly stressed at the inner bearings or those near the differential. Our experience with this type of axle has been that, if a semi-floating axle breaks, it breaks near the outer bearings. It is beyond a shade of doubt that the shafts are most highly stressed in this position.

If we consider Mr. Favary's figures as shown in his Table 1, we find a maximum stress in a semi-floating axle near the wheel bearing of 8550 lb. per sq. in.; near the differential bearing the stress is 23,390 lb. per sq. in. In the case of the full-floating axle a fiber stress of 23,390 lb. per sq. in. is determined in both cases. The following is a presentation of my views relative to axle stresses.

The stress of an axle should be based on the torque requisite to slip the wheels. With Mr. Favary's figures of a 9000-lb. load per wheel and a coefficient of adhesion of 0.6, we obtain a torque moment of $M_t = 9000 \times 0.6 \times 18 = 97{,}200$ lb-in.

The bending-moment is an aggregate of the static bending-moment and the dynamic bending-moment. The static bending-moment is determined by the load of 9000 lb. acting on a lever-arm of 6 in. Hence $M_{b_1} = 9000 \times 6 = 54{,}000$ lb-in.

The maximum dynamic bending-moment will be encountered if the truck should be skidding. This dynamic bending-moment is $M_{b_2} = 9000 \times 0.6 \times 18 = 97{,}200$ lb-in.

The aggregate bending-moment is the sum of both; or, $M_{b_1} + M_{b_2} = M_b = 151{,}200$ lb-in.

The dynamic bending-moment due to brake application or acceleration is omitted for obvious reasons. The combined torque and bending-moment we obtain from the well-known formula

$$M_c = (0.35 \times 151{,}200) + 0.65\sqrt{(151{,}200^2 + 97{,}200^2)} = 169{,}900 \text{ lb-in.}$$

The stress is $169{,}900 \div 6.28 = 27{,}100$ lb. per sq. in. From this we note that the stress in the semi-floating axle near the wheel will be about 27,100 lb. per sq. in.

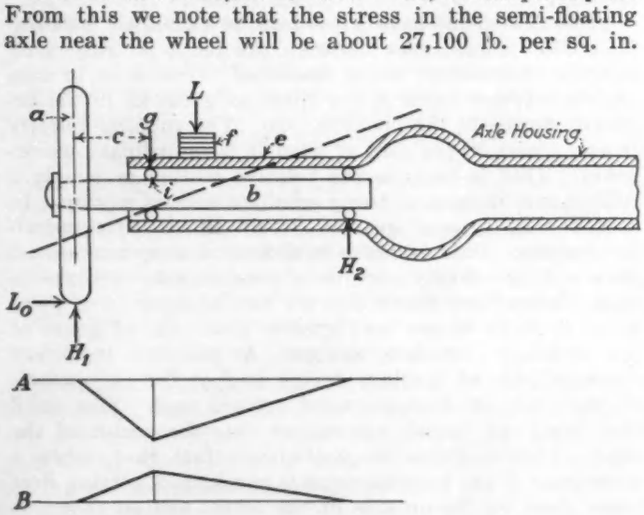


FIG. 35—DIAGRAM SHOWING RELATION OF STATIC RADIAL AND DYNAMIC LOADS IN A SEMI-FLOATING AXLE WHILE THE CAR IS SKIDDING

S. A. E. Steel specification No. 2340 in such large diameters as 4 in. usually cannot be expected to allow any more than a 120,000 lb. per sq. in. elastic-limit, considering a commercial run of steel with a low carbon-content. This gives us a factor of safety for the semi-floating axle of $120{,}000 \div 27{,}100 = 4.4$.

In case of the full-floating live-axle, we have a maximum torque-moment of 97,200 lb-in. This gives a stress of $97{,}200 \div 2.84 = 34{,}250$ lb. per sq. in.

A shaft of 2 7/16-in. diameter can be heat-treated safely up to a 145,000 lb. per sq. in. elastic-limit and still be within the realm of manufacturing possibilities. This gives us a factor of safety of $145{,}000 \div 34{,}250 = 4.25$. From this we note that, to all intents and purposes, the two shafts are designed with about the same factor of safety. However, the stresses in the semi-floating axle are reversed with every revolution of the road wheel, from a positive maximum to a negative maximum. This, according to Wöhler's test, is about the worst loading that can be put upon any part. For this reason the factor of safety of a semi-floating shaft should be at least 2½ times as large as that of a full-floating-axle shaft, because the latter is stressed to a maximum uniformly throughout the whole range of driving, with the only exception of occasional use of the reverse gear.

To sum up the situation, I would say that Mr. Favary considers the full-floating live-axle for the 5-ton truck as being 2½ times safer than the semi-floating shaft.

E. FAVARY:—In his statement that the full-floating axle has a factor of safety of 4.25, Mr. Burkhardt considers the rear wheel as slipping on the ground. I discussed this in my paper and said that the wheels will slip when a shaft brake is employed. In the case that Mr. Burkhardt has considered we will obtain a maximum torque-moment of 97,000 lb-in., which is as mentioned in my paper. Taking the smallest dimension of the shaft, that is, 2 7/16 in. in diameter, we find that the polar section modulus of this is 2.84, and that this gives a stress of 34,250 lb. per sq. in. He says that this is the stress in the small end of the shaft and I agree with him. But when Mr. Burkhardt states that steel, heat-treated, has an elastic-limit of 145,000 lb. per sq. in., I entirely disagree with him, because he is considering the elastic-limit in tension and in compression. He admits that we only consider the torque in the full-floating axle; hence, why should we consider the tensile and compressive strength of the steel? We must consider the torsional stresses, which are purely shearing stresses; therefore, on the face of it, knowing that the elastic-limit in shear to be only about 35 per cent of the elastic-limit in tension or compression, it is as I have shown, about 54,000 lb. per sq. in. Let us assume that this elastic-limit of the material in shear or torsion is 55,000 lb. per sq. in. If we divide this by 34,250 lb., we get a factor of safety of less than 2; therefore, in the case of the full-floating axle, where the stresses are purely torsional, I cannot see why Mr. Burkhardt considers the elastic-limit of the material in tension or compression and I hold this to be an error.

With regard to the semi-floating axle, Mr. Burkhardt says that the static radial-load must be added to the dynamic load when the car is skidding. In Fig. 35 the wheel of the car is marked *a*, the axle *b*. The distance *c* is 6 in. The axle housing is indicated by *e* and the spring by *f*. The load *L* on the spring will be pressing downward at *g* and will be resting on the bearing *i*. Under normal load, the top of this bearing will carry the load. Considering the reaction at H_1 and H_2 due to the static load *L*, a positive bending-moment will be created in the

shaft. If the distance c is 6 in. and the load 9000 lb., we have a maximum positive bending-moment of 54,000 lb-in. as shown at A.

Mr. Burkhardt says further that when the car is skidding the dynamic bending-moment is 9000 times the coefficient of friction of 0.6; that is, one-half of the normal load on the rear of the truck, and this is also 54,000 lb-in. I do not agree with Mr. Burkhardt's contention. When the car is skidding sidewise, we must consider the centrifugal force that will tend to shove the car to one side. When that happens the inner wheel is relieved of a certain amount of load and the outer wheel will carry more load as shown in Fig. 1 of my paper. Hence, to begin with, this load is not 9000 times 0.6, but we must calculate the force that causes the car to skid and, as I showed before, this amounts, on the outer wheel, to 10,600 lb. and is the force tending to skid the wheel.

To find the bending-moment due to skidding, consider this force and imagine the left wheel to be skidding to the left. In Fig. 35, L_o is the reaction working in the opposite direction and this creates a negative bending-moment in the shaft, as shown at B in Fig. 35, which must be deducted from the positive bending-moment. Therefore, I disagree with Mr. Burkhardt that those two stresses should be added; in fact, the bearing load due to one load alone may be considerably higher than that due to the two, because the static radial-load is supported by the top of the bearing at g, whereas, when there is a tendency to skid, the shaft will tend to deflect as shown by the dotted line and impose a load at the bottom of this bearing i; hence, we must deduct this load from the former.

A MEMBER:—Can you add it on the inner wheel?

MR. FAVARY:—Yes, but a load of only 300 lb. was left on the inner wheel. The maximum stresses are on the shaft of the outside wheel, because the loads on both wheels do not remain the same when the car skids, and Mr. Burkhardt has not taken that into consideration.

HERBERT CHASE:—Will not the static load on the outer wheel increase?

MR. FAVARY:—Yes, the static load will increase from 9000 to 17,000 lb. as I have shown, and the skidding force will be the radial load multiplied by the coefficient of friction; this amounts to 10,600 lb., as stated in my paper. The bending in the shaft due to skidding will act in the opposite direction and hence we obtain a negative bending-moment due to the skidding and a positive bending-moment due to the static load; therefore, one will counteract the other, and the result is less than that due to the maximum radial-load alone.

Mr. Burkhardt states in the beginning of his discussion that I find the semi-floating axle most highly stressed at the inner bearings, the inner bearings being those near the differential. The stress in a shaft depends on its dimension and I simply stated that if the shaft were tapered, as shown in Fig. 11 of my paper, the shaft being so much smaller near the inner end than at the outer end, I found the metal much more highly stressed near the inner bearing, since the polar moment of inertia here is 2.6 and near the outer end it is almost 12, or nearly four times that near the inner end. By increasing the diameter at the inner end of the shaft, we can easily reduce the stresses. The bending-moment is very much greater near the outer end, but if the diameter of the shaft is here so much larger, as shown in Fig. 11, the stresses are less than at the inner end. The resultant load on the bearings is less than that due to the maximum radial-load, on account of the skidding force, which I have taken into account, but which Mr. Burkhardt is not considering; he adds them together and that is not a true condition of the facts under the conditions assumed when the car skids.

W. F. ROCKWELL:—Mr. Burkhardt's point that the heat-treating in a large shaft may cause considerable trouble, is referred to in a discussion before the British Institution of Automobile Engineers in which very careful tests made on a large billet in connection with gun-forging work and the heat-treatment of gun forgings were reported. Apparently, there was practically no difference in the strength of the test-pieces cut out of various parts of a very large billet that had been subjected to heat-treatment somewhat similar to that employed in axle heat-treatment.

Mr. Burkhardt has said that, in the 5-ton sizes, the full-floating axles can be made lighter in weight than the semi-floating axles. The statistics on American stock axles for 1922 have been published[5] and, inasmuch as the figures were given by the truck-axle manufacturers themselves, there hardly could be any claim of prejudice. If those figures are examined, it will be found that there are at least one or two designs of semi-floating axles of 5-ton capacity that weigh considerably less than full-floating axles of the same rated capacity.

Current statistics show that, in the passenger car field, there has been a very decided increase in the production of semi-floating rear-axles. Semi-floating types increased 15 per cent during the past 3 years, while full-floating construction has suffered a loss of 20 per cent. The majority of live-axle truck-designs in this country has always followed the semi-floating type. In actual tests, it has been proved that skidding into a curb will demolish the wheel without injuring the semi-floating shafts; whereas, in full-floating jobs, such accidents usually bend a tube in addition to breaking the wheel, and the cost of repairs is increased greatly. It happens occasionally that a full-floating tube is bent by a skidding accident, and that the owner is not aware of the trouble until several shafts break in succession; investigation then shows the cause to be a bent tube.

Mr. Favary's calculation of bearing loads proves beyond a doubt that better distribution is possible with a semi-floating design. The great leverage existing, because of the increased distance between semi-floating-shaft bearings, reduces the bearing load due to skidding so that it is less than 30 per cent of the load imposed with a full-floating hub-and-shaft design. For equal capacity, semi-floating axles weigh less than full-floating axles. If the track is the same in full-floating and semi-floating axles, the distance from hub-cap to hub-cap for full-floating axles is usually considerably greater, and there is a decided increase in accidents when the hub-cap or driving flange extends far beyond the tire rim. Other advantages of the semi-floating design are a great reduction in the number of parts and a better distribution of the stresses incident to torque and braking.

With reference to bearing loads, the design shown in Fig. 12 of Mr. Favary's paper differs from the great majority of worm-drive axles in the method by which the worm-gear thrust is taken care of in the differential mounting. In forward drive, the worm-gear thrust is taken by the left-hand bearing; whereas the usual design places this thrust on the right-hand bearing. In this design the bearing loads are very nearly equal on each differential bearing; whereas in the other design the right-hand bearing takes a resultant load approximately 100 per cent greater than the left-hand bearing.

[5] See *Automotive Industries*, Feb. 16, 1922, p. 388.

Our design can, therefore, be symmetrical without being unbalanced and, for the same size of bearings, the factor of safety in our axles is double that of the usual design. It will be observed also that the adjustment of the wormgear is made by the use of threaded nuts on the differential hubs, while some other designs employ shims. The use of four-pinion bevel-gear-type differentials throughout accords with the best American practice for greatest strength combined with compact light construction. The use of the two-pinion differential cannot be justified, except on the grounds of reduced first-cost, which is offset by increased maintenance.

It will be observed that the wormgear is clamped between the differential side case flanges and the drive is taken by bolts that are in shear at two points. This has an obvious advantage over the single-flange differential-case that is sometimes used.

Two concentric brakes, both internal-expanding, cam-operated, are employed in this design. The external-band wheel brake practically has been eliminated on trucks in this Country, because the brakes are liable to be torn off whenever skid chains are used and a cross-chain breaks. The mud and grit that finds its way between the external brake and the drum has a tendency to cut into the drum very rapidly. The internal cam-operated brake is the only internal brake that will not freeze up and become inoperative when covered with slush and ice in cold weather. The use of two drums on each wheel permits braking first on one drum and then on the other in hilly country, so that there is no overheating. The flanges on the service brakes prevent them from being distorted, although the tendency to distort is very slight with an expanding brake of this type. Hinged and quadrant brakes have a much greater tendency to distort the drums permanently. Concentric arrangement gives the largest possible braking surface without sacrificing the strength of the load-carrying member. Considering the wheels as columns supporting a beam, the closer the load is placed to the column, the greater the factor of safety is for the same beam. With narrow drums, the springs that carry the load to the beam can be placed very close to the wheels, which act as supports.

One of the principal points of discussion concerning brakes is whether the propeller-shaft or transmission brake has any advantage over the rear-wheel brake. From actual experience with both types of brake, we have drawn the following conclusions: A brake on the transmission or the propeller-shaft requires much larger transmission members in the axle because the braking torque imposed on the rear axle cannot be estimated as closely as engine torque and, in any case, is considerably greater than it is possible to impose by wheel brakes. Although the braking effort with the transmission brake is less, any advantage is offset entirely by the fact that it is very easy to make the braking effort too extreme, with disastrous results to the axle transmission members. If the rear wheels are locked, any further braking effort is useless; we have demonstrated that, with good rear-wheel brakes, the rear wheels can be locked, bringing the truck to a stop in a minimum distance. The use of a transmission brake would not permit the truck to stop any sooner and, if its application caused the destruction of a shaft, the braking effect would be nullified immediately. In actual trials, this has happened and serious damage has been done. A driver, going up a hill, may suddenly discover that his truck is slowing up; it may start to roll back down the hill, gaining considerable momentum before he discovers that his transmission brake is useless, because his propeller-shaft or axle shaft has broken.

It must be obvious that with the much higher relative surface speeds of the propeller-shaft brake, the wear will be very much greater. While the life can be prolonged by increasing the width of the drum and the brake-band, the cost of replacing linings frequently will be considerably greater than with wheel brakes.

There have been many discussions as to which form of drive will survive finally. Statistics show that the chain drive practically has been eliminated. The bevel-gear drive is increasing for light trucks and seems to be a logical development because of its simplicity and low cost. The internal-gear drive is losing ground and at least two of the leading internal-gear-drive manufacturers are building bevel-gear drives this year. The worm drive seems to continue in its popularity, and the double-reduction gear is showing a fair increase. As two of the largest builders of trucks have adopted the double-reduction gear recently, there is little doubt that its future is established.

I believe that both worm-drive and double-reduction-gear-axles have their particular use and place. Disregarding the chain drive, the British manufacturers seem to be about evenly divided between the double-reduction and the worm drive. None of them uses the internal-gear drive in the wheels, as shown by the statistics for Tendencies in British Truck Design[6] for 1922, although that form was used some years ago. It will be observed also that a large number of manufacturers, including Guy, Leyland, Maudsley and Pagefield, use both the worm and the double-reduction-gear drives.

The worm drive has several advantages that put it in a class by itself. It has a small number of parts and general simplicity. This is only approached by the bevel-gear drive. With a ball-bearing mounting, the rear bearings of the worm are permanently mounted and the front bearing is free to float. The only bearing or gear adjustment of any kind in this form of ball-bearing worm-drive axle is in the differential mounting, where two threaded nuts provide the complete adjustment for the worm and the gear. Even a bevel-gear axle requires adjustment in another place, the pinion shaft. The worm drive's second great advantage is its absolute quietness in operation, which no other form of gear can provide with such assurance of permanent satisfaction.

The double-reduction axle, consisting of one set of bevel gears and one set of spur gears, which is used in England, and also in this Country by Mack, Autocar and Ruggles, has a few more parts and may develop noise if not well made and properly adjusted. It has an advantage over the worm gear in its wide range of efficiency. The worm gear can be made very efficient for a given load and speed, but not throughout an extremely wide range of loads and speeds. The double-reduction axle has a disadvantage compared to the worm in that it has a larger number of parts and a few more adjustments, but this is offset by the better distribution of the direct loads and stresses imposed by accidental shocks; in case of failure from any of the usual causes such as lack of lubrication, overload or accident, the consequential damage is less. The side-thrust on the differential case and the mounting supports is eliminated.

The internal gear is a form of double-reduction that involves more parts. The use of internal gears in the wheels makes the lubrication problem extremely difficult,

[6] See *Automotive Industries*, Feb. 16, 1922, p. 363.

and any attempt to eliminate it makes the parts less accessible and increases the cost of repairs. Some of these designs now use as many as 10 gears and 16 bearings. While this distributes the stresses and the wear, it must decrease the efficiency because every gear and bearing reduces the amount of power transmitted to the rear wheels. Furthermore, in the case of failure of some small part, the consequential damage may include several broken gears and bearings. Additional gears will produce noise and, if one gear wears unevenly, all the gears in contact must suffer.

The internal gear has claimed the advantage of lighter weight but, according to the reference previously given,[1] both worm-drive and double-reduction axles of larger capacity actually weigh less than one standard make of internal gear. The light weight in the internal gear is liable to be secured at the expense of rigid construction. In other words, an internal-gear axle may be strong enough to carry a load and transmit the power, but its flexibility throws the bearings and the gears out of alignment to such an extent that it results in noise, a short life of the gears and the bearings and a loss of efficiency. The efficiency is further reduced by the impossibility of obtaining perfect lubrication.

There have been many lengthy discussions and many fantastic claims based on the advantages to be gained by reducing unsprung weight. If unsprung weight were the sole desideratum, we should never have abandoned the chain drive. There is one claim that a 1-lb. reduction in the unsprung weight is the equivalent of a 10-lb. reduction in the sprung weight. Many engineers and salesmen using this claim do not know what this is founded upon or to what it refers. It is based on tests made by the Michelin Tire Co. many years ago, from which a conclusion was reached that the wear on the tires is increased as much by 1 lb. of additional unsprung weight as by 10 lb. of sprung weight. No reference was made to the general wear-and-tear on the vehicle, nor was the test intended to determine any variation in the fuel-consumption of the truck. Mr. Favary points out that 100 lb. at the center of the axle has less effect than 100 lb. added to the weight of the rear wheels. This brings out a disadvantage inherent in both the full-floating construction and the internal gears in the wheels. For the same total axle weight, both constructions bring a disproportionate weight directly over the tires.

From current practice, it is easy to prove that if the unsprung weight is reduced so much that the bearings and the gears suffer from misalignment, any saving in tire wear is offset many times over by upkeep and repairs on the axle itself. It has been claimed that additional unsprung weight made vehicles ride more easily, and also that the heavier axles hold the road better, so that the tires actually wear longer up to a certain point in increased axle weight. One will find automobile men to-day who avow easier riding qualities for the old-fashioned passenger-axle with transmission attached, which was an extreme example of great unsprung weight.

I believe that a reduction of the unsprung weight is desirable up to a certain point, but that it easily can be carried to an extreme. We have some definite figures on a saving accomplished by a reasonable reduction in the weight. A 5-ton axle weighing 1570 lb. was substituted under a used truck for another make of axle weighing over 2400 lb. Both axles were of the same type with ball bearings throughout; there were no radical structural differences. No other changes were made in the chassis. The test lasted 2 weeks, during which time the truck averaged 49 miles per day. There was a saving of 5 gal. of gasoline per day, which could be explained only by the difference in the weight of the rear axles.

We have some figures on the deflection of the load-carrying members that were obtained from the chief engineer of one of the leading truck companies that has used several types of axle. Three worm-axle housings of different standard makes of 1½-ton semi-floating axles were tested under static loads. The housings were supported at the wheel-bearing locations, the load was applied evenly on the spring-pads and the deflection was measured at the center of the axle. The lightest housing, constructed of pressed steel, showed a ¼-in. deflection for an 11,000-lb. spring-pad load, a ½-in. deflection for a 16,500-lb. load, a 1-in. deflection for a 21,000-lb. load and complete destruction at a 23,000-lb. load. The heaviest housing, constructed of cast steel, showed a ¼-in. deflection at 30,000 lb., a ½-in. deflection at 49,000 lb. and a ¾-in. deflection at 56,000 lb., at which point cracks developed. The malleable housing, which was heavier than the pressed-steel housing by 50 lb. and lighter than the cast-steel housing by 70 lb., showed a ¼-in. deflection at 26,000 lb., a ½-in. deflection at 45,000 lb., a 1-in. deflection at 52,000 lb. and no signs of cracking at 56,000 lb., which was the peak capacity of the hydraulic press. Remembering the effect of simple static-loads, we call attention to the necessity for sufficient stiffness to protect the bearings from the excessive deflection that shortens their life, decreases the efficiency and increases the maintenance losses. These are figures for heavy scientifically designed housings. The deflection of solid-round load-carrying members frequently is found to exceed ⅜ in. under static load equaling ordinary requirements.

It is our opinion that it is impossible to determine which form of drive will survive and whether any present design will survive, because it is impossible to forecast the tendency in engine design. The passage of laws regarding the speed of trucks may have a considerable effect on design. The tendency seems to be toward a larger number of radically different axle designs rather than toward the standardization of any one particular type.

Every axle now on the market as well as every contemplated axle, represents a compromise in which some advantageous features are sacrificed so that the designer can incorporate features he believes to be essential. No engineer would use a solid-round load-carrying member except to reduce the cost of the rear axle. We might recommend the overhead worm-drive for bus service, if the desire to lower the floor-boards did not militate against it. If the bus builder insists on the lower floor-board design, he must either invert his worm-drive axle or use another form of rear axle. Inverting the worm has three serious disadvantages; it (*a*) reduces road clearance too much; (*b*) calls for too great an angle on the propeller-shaft; and (*c*) results in poor operating conditions, inasmuch as sediment has no chance to settle in the bowl and constantly runs through the worm bearings and over the worm-gear surfaces. The same trouble is experienced with internal gears, because no sediment or grit can settle to the bottom of a chamber but is continually circulated around in the lubricating medium, thus destroying the gear surfaces and the bearings.

It might be well to point out that the extreme angle of the propeller-shaft cannot be corrected by tilting the rear axle, as is occasionally attempted, without introducing a serious complication. If the transmission shaft and the

[1] See *Automotive Industries*, Feb. 16, 1922, p. 388.

rear-axle worm-shaft or bevel-pinion shaft are parallel, the harmonic motion introduced by one universal-joint can be offset by the second. If the rear axle is tilted, the harmonic motion is transmitted and a short life of the bearings and the gears will result, with possible additional damage to the engine.

The axle designer who believes he has perfected the one satisfactory type is reckoning blindly. One of our customers is producing a satisfactory steam truck. Others are experimenting with very interesting new types of engine. He would be very rash who would attempt to forecast the developments of the next few years. The progressive manufacturer will encourage designers to work diligently, because there is always room for improvement. If any present design is perfect, the reduction of cost provides considerable material for study. If the first cost of all types of axle were the same for equal capacity, several types now purchased because of their low first cost would disappear in an extremely short time. As both the worm-drive and the double-reduction types are high in first cost, and both have increased in production while other designs have decreased, we can consider that they will continue in use until something better shall be designed or something equally good produced for less money.

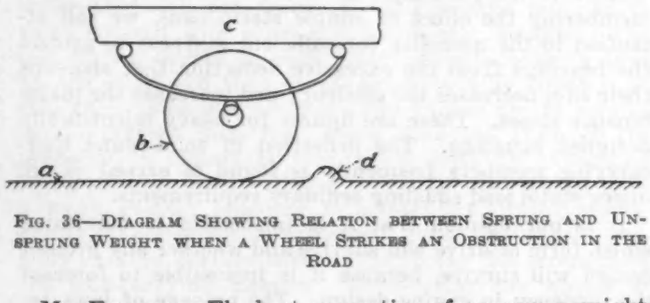


FIG. 36—DIAGRAM SHOWING RELATION BETWEEN SPRUNG AND UNSPRUNG WEIGHT WHEN A WHEEL STRIKES AN OBSTRUCTION IN THE ROAD

MR. FAVARY:—The best proportion of unsprung weight is a very interesting topic. We sometimes hear that the unsprung weight should be just so much, but not less. Suppose a road surface *a*, as shown in Fig. 36, and that we have one small unsprung weight *b* below and a heavy weight *c* above. There is a spring between the unsprung weight and the sprung weight. When the unsprung weight, which is carried by the wheel, moves over an obstruction *d*, it will be propelled upward with a certain velocity. The velocity and the acceleration will vary, but assume that the maximum velocity is attained when the wheel reaches the top of the obstruction. The unsprung weight will have a certain amount of kinetic energy which will propel it higher up, and this kinetic energy will be imparted to the unsprung weight above, through the spring. It is evident that the heavier the unsprung weight is, the greater will be the kinetic energy and, therefore, the upward thrust, even after the wheel leaves the obstruction, will be greater. On the other hand, if the unsprung weight be little or if we assume first that the unsprung weight has no weight, the sprung weight remaining the same, the unsprung weight, not having any kinetic energy, would follow the contour of the obstruction and come to the ground immediately after the wheel left the obstruction.

In practice, the unsprung weight must have some kinetic energy, the amount depending on the speed and on the mass that is thrust upward. Hence, the greater the kinetic energy is, the more the body will be moved upward, and the greater will be the shock imparted to the unsprung weight.

ALFRED F. MASURY:—I disagree with Mr. Myers on the matter of standardization. I do not wish to fight the war over, but we all know the story of the Hispano-Suiza engines that did the work while we, in this Country, were frantically standardizing. I think we all know also that the Peerless, the Pierce-Arrow, the Mack and the Four-Wheel-Drive trucks were doing the work at the front while we were trying to standardize Class-B truck-axles. We ought to keep away from the standardization of axles. One of the truck-axle designers has said that there will be many more different types of axle, and I think that will be true.

If we look at the passenger-car companies, the ones that have had the least standardization probably have been the most successful. The Ford, Dodge, Franklin and Stanley steamer companies have gone through this trying period with flying colors, making money. Considering the truck companies that have gone through this period without actually losing millions of dollars, such as the Autocar, the International Motor and the Fifth Avenue Coach companies, I think we can say that any one of those companies has had less standardization than some of the organizations that have lost as high as $8,000,000 in 1 year; so, I think it is fair to say that we should keep away from axle standardization, except within certain limits.

On of the new things in the motor-truck industry at present is the rail motor-car. There is hardly a large truck organization that does not have some form of rail motor-car running on the railroads. The railroad engineers as a whole are one of the best educated and most highly trained class of engineers we have. Why did they not build rail motor-cars? Simply because they are surrounded with the Master Car Builders' Standards. We do not want the Society to become a mass of standards that will take the initiative out of its engineers. Therefore, I think it is fair to say, we will not get all the motor-vehicle axles alike.

Shall we take the initiative out of this Country and the opportunity of each engineer to express his notions, even though some of them may be bad? I believe we are doing harm when we say that we should standardize anything as important, and on which the industry has as many things to learn and do, as rear-axle design. As an illustration, when the Pierce-Arrow company first came out with its worm-drive axle, it certainly did prosper on that axle and on that whole truck, which was entirely different from anything we had seen in this Country. We could go on citing cases almost indefinitely. Of course, a man must be right to a reasonable degree and be fairly good as an engineer, have a good organization back of him, a good manufacturer and good materials; but if a man believes in some particular type of design that can be based on good engineering, we should do nothing to hinder him in expressing those ideas.

I would like to add that the company with which I am associated built worm, chain and double-reduction axles and made tests of these three types of axle. We used three trucks, had the engines governed alike and changed drivers. We made five different types of test. In one, we started the trucks moving and let them coast; in another one, we ran them up a grade to see how far they would go before getting into second speed; in a third, we started them all on a hill and noted how fast they would go up to a certain point; in a fourth, we backed them up to a curb to see which one would climb over the curb; and in the fifth test a dynamometer recorded the number of pounds that each truck could pull. In each of

these tests the chain drive showed the best; then came the double-reduction and then the worm drive. I think that is perfectly easy to explain. We have more surface and contact and thus better lubrication; and I think that is the whole story.

I want to mention one other thing. I think the best spring-shackle is Mr. Myers' design but, supposing that spring-shackles had been standardized, we never would have had the wick lubrication that he has worked out very satisfactorily on many trucks.

MR. MYERS:—Mr. Masury cited two or three car builders as examples of manufacturers who did not standardize. I have no desire to limit the initiative or originality of any engineer and, in that matter, I am sure the S. A. E. Standards policy coincides. There are many inconsequential details in axle construction that should be standardized. When we have enough experience on units that we may be building to say what is good practice and what is poor practice in regard to its details, let us stop making variations in those details that simply call for additional sets of spare parts in every service-station in the Country. Such practice is not logical.

Mr. Masury cites the Master Car Builders' Standards. There is no better exemplification of the good that could come to a transportation industry than those very standards. The reason that railroad cars can be built so cheaply, serve us so well and run great distances from their place of origin is that, even when a railroad car has run this 1000 or 2000 miles from home, the service-station car-shop to which it happens to be sent for repair has parts that will fit, all made to the Master Car Builders' Standard specifications. If the railroads are reaching out to obtain cars propelled by gasoline, not having conceived that idea themselves, since they were endeavoring to perfect their own type of apparatus, they very naturally reach over into the automotive industry and pick out what they think will be of use to them. In Mr. Masury's specifications for his rail motor-car, I notice that he specifies that the front trucks are to be built to the Master Car Builders' Standards. It is futile to argue this question of standardization again, because we all know the good that has been accomplished already and it has yet to be shown that standardization has limited initiative or cramped design.

The value of unsprung weight has been discussed in this Country for about 18 years, with reference to automobiles. So far as I know, there is no evidence to substantiate any such faciful ratio as 5 to 1, 7 to 1, or 10 to 1, for the weight below the springs to the weight above the springs. For more than a year I was in fairly close touch with a test made by a very large truck operator in one of the metropolitan cities. It is described in my paper. Notes on Motor Trucks.[3] Four trucks of about the same load capacity were used. It was discovered that the tire mileage was greater on the two worm-drive trucks than on the two chain-drive trucks. The unsprung weight on the worm-drive trucks was 70 per cent in excess of that on the chain-drive trucks. The load per inch of tire width on the chain-drive trucks was about 6 2/3 per cent in excess of the corresponding load on the worm-drive trucks.

Leaving out all questions of unsprung weight, one would naturally expect that the wear on the tires for the worm-drive trucks would be somewhat less, in that they were loaded a little less per inch of tire width. We might expect 10 per cent more tire wear on the chain-drive trucks. The actual difference was about 31 per cent in favor of the worm-drive truck. But this does not prove that the heavy axle is better than the light axle.

We all appreciate that theories help us to solve problems, but we do look for some substantial tangible results, something we can define as actually having saved us money somewhere. I think Mr. Favary should have gone somewhat further with this subject. He says that the impact of the unsprung weight on the vehicle load, with the heavy axle, will be greater than that with the light axle. That may be true, but it is not in direct proportion, much less a ratio of 5 to 1 or 7 to 1. The tire must and does absorb much of the shock due to the greater inertia of the heavier axle. From this it is inferred falsely that the tire must wear more. But I have never been able to find out that this greater weight affected the tire wear to any substantial extent, and I have checked it since the time when we were first able to get records on the worm-drive trucks versus chain-drive vehicles. In 1912 and 1913 I could not find that the tire wear on the Pierce-Arrow worm-drive trucks was any greater than that of the Packard or any other chain-drive trucks in use at that time; in fact, what data were secured pointed the other way. We need more information on this subject of unsprung weight. It is not fair to make assumptions and statements concerning unsprung weight unless there is substantial evidence with which to back them up.

MR. MASURY:—Mr. Ford and Mr. Dodge have their own standards, and not those of any outside organization. With regard to the standards on the railroads, they are not particularly attractive as to the working out of cheap transportation when judged by railroad earnings.

A. G. HERRESHOFF:—The Fifth Avenue Coach Co. employs both worm and internal-gear axles for its coaches. This company commenced operation with DeDion chassis. The axles were of the internal-gear type, the differential assembly being bolted to the chassis frame and therefore constituting sprung weight. No mention has been made of this character of axle.

In 1915, the Fifth Avenue Coach Co. commenced the production of its own equipment, known as type A; the rear axles were worm-driven. In 1918, a second type was evolved, the type L. These vehicles are hung very low and internal-gear axles are used.

Of the different types of axle above mentioned, there is the least unsprung weight with the DeDion; next comes the type L, the heaviest being the type A. It is rather difficult, however, to give any correct data in regard to the relative tire-wear. Naturally one would expect the best results with the axles showing the least unsprung weight. But it will be realized that the development and employment of these axles has been spread over a long period and during this time many improvements have been made, particularly by the tire manufacturers, the net result of which is that the Fifth Avenue Coach Co's. tire mileage to-day is much greater than it was when the DeDion vehicles were in service.

DR. H. C. MCBRAIR:—Mr. Favary stated that one should not use a reduction of greater than 6 to 1, but I believe that it is perfectly possible to go to at least 9 or 10 to 1 with spiral bevels; in fact, he shows the spiral bevel with a six-tooth pinion.

The double-reduction axle seems to be the coming type. It ranges from vertical to 90 deg. from vertical. What is now needed for efficiency is a good two-speed axle of simple construction and low cost, that can be made for a chain, an internal-gear or a double-reduction drive. This would give four speeds, which would include an extra low and an extra high, with only a low and a reverse in the

[3] See THE JOURNAL, October, 1922, p. 333.

gear-box. An axle of this kind should increase the tire mileage by 50 per cent and also would reduce the repair bill. It would allow a full load to be carried over good roads on the extra-high gear with only one-half the engine speed and would carry the same load over ordinary hills or heavy roads on the regular high-gear, thus eliminating the heavy losses in the gearbox.

In reference to the axles for railroad work, an axle is made by the Wisconsin Parts Co., of the double-reduction type, that has two bevel-gear rings and one pinion. This axle gives the same speeds forward or reverse. Another type has three speeds forward and a reverse, all direct, for a chain drive. In the car, the engineer, who was not an automobile engineer, placed his powerplant on the truck, thus providing a drive-shaft less than 6 in. in length.

In talking with railroad men, I find that they all criticize the car that is made from a truck design. They say that the axle is too far from the powerplant and that, with a Hotchkiss drive or radius-rods on an ordinary truck, the two wheels on the rear axle have a tendency to follow a siding or switch if the latter is on the outside of the curve, because the weight of the car and its passengers throw the axle out of alignment in the wrong direction. One railroad official has refused to allow such two-wheeled axles on his road, but he has allowed the four-wheeled truck.

MR. FAVARY:—Referring to Mr. Myers' remarks about unsprung weight, if the load is the same, that is to say, the sprung weight, the engine power and the springs, then the lighter unsprung weight will be more advantageous. Unless we have the exact data under the conditions named by Mr. Myers, we cannot consider two trucks, one perhaps running at a much greater speed than the other, or one having better springs than the other, as a criterion; but, if all of the conditions are alike, save the unsprung weight, I maintain that the unsprung weight will affect the riding quality and the wear of the tires in direct proportion to its lightness. Nothing that I have heard so far would make me change that opinion.

Regarding Dr. McBrair's remarks on the limit of reduction of 6 to 1 for the double-gear drive, I simply said that, ordinarily, we find that the limit of the reduction of bevel-gear drives is 6 to 1, but I believe this will not remain the limit, nor do I think that the final word has been said on any one of these different types of axles, including the internal-gear-drive axle. We are looking forward to many improvements.

R. E. FIELDER:—The coaches with axles such as Mr. Herreshoff has referred to were in operation between 1907 and 1913. Approximately 160 of these vehicles were used in all. It is interesting to note that our average tire-cost taken over this period was 3.36 cents per mile and that the present figure is 0.86 cents per mile. There are, of course, many reasons for this decrease; for example, better tire manufacturing methods, improved vehicle design including decreased weight, and particularly unsprung weight, the standardization of metal wheels and, last but not least, closer operating and repair supervision.

Obviously, the unsprung-weight factor is very important, from the standpoints of tire and of road wear; and if we lose sight of the latter, we may soon face heavy taxation as a direct result, particularly bearing in mind the unquestionable possibility of a much more general use of the highways by motor coaches.

Mr. Burkhardt has stated that with solid axle-shafts of large dimensions, difficulties might be expected in connection with heat-treatment. We have not found this to be the case. The axles of all our type-A coaches are of the semi-floating type. The drive shafts are of large size. They are made from 3.5-per cent nickel 0.40-per cent carbon tubes. Parallel tubes are cut to suitable lengths; then the ends are swaged taper. This construction has worked out exceedingly well, and so far no failures have been experienced. It should be mentioned that this type of drive-shaft is approximately 66 lb. lighter than the original solid-shaft design.

From the standpoint of the large operator, it is highly desirable that wheels be readily removable. The ideal is to be able to take off a wheel without disturbing any other part. In cases where it is necessary to remove the bearings and the like, there is always a possibility of the introduction of dirt or other foreign matter, and great care must be exercised in connection with the reassembly and adjustment. Generally speaking, it is necessary to remove wheels during the inspectional period and also where the tires require renewal. The process of wheel removal should be made so simple that it can be carried out safely by the most unskilled type of workman.

Referring to Mr. Favary's remarks in connection with the unsprung weight, certainly we dislike weight in any form; but we believe that weight at the center of an axle is less harmful than at its outer extremities, that is, at the wheels, for it is seldom that both wheels of a vehicle make contact with a bump or depression at the same time. Usually, one wheel only is affected. Assuming for example, that one wheel mounts a ridge 2 in. high, the movement at the center of the axle will be approximately 1 in.; therefore, the kinetic energy in the mass will be less if the bulk of the weight is located at the center of the axle than if its location were at the outer extremities.

MR. MASURY:—How much mileage has the axle of the newer internal-gear type made? How has it worked?

MR. FIELDER:—Our type-L coaches, which are equipped with internal-gear axles, are being operated in New York City, Detroit, Baltimore and Pittsburgh. The largest operation is in Detroit where there are approximately 70 of these vehicles, the majority of which have done 18 months of service or more. Quoting recent figures, the lowest mileage of any coach is approximately 40,000 and the highest approximately 80,000. According to official statements issued by the Detroit Motorbus Co., exceedingly good tire-mileage is being obtained, this being at least equal to that in our own operation here in New York City.

MR. FAVARY:—I believe we must discard everything we know so far as tire mileage of a few years ago is concerned, when we make a comparison with present-day tires. As Mr. Fielder has indicated, the tires are different to-day; the quality of the tires is very much different from what it used to be.

Lighter unsprung weight does not damage the road so much. The two are interrelated because, the heavier the blow against the road surfaces is, the heavier the blow against the tire will be. However, here also we can make no comparison unless we have tires of the same quality.

SAMUEL H. WOODS:—We have heard very little about axle housings. In the dual-reduction axle housing, we are using a single drop-forged member. In so doing we are naturally getting the benefit of material that has been pretty thoroughly worked as compared with a cast or built-up structure. Also, we are able to forge on the spring-saddles, thereby getting away from the weakening effect of attachments by riveting or other means. In the same axle, due to our peculiar carrier construction, we

have extreme accessibility not only of the entire differential carrier, but of its various components. For instance, we can remove the pinion and bearings or the countershaft and its bearings. In that way we can change the gear-ratio very easily.

CHAIRMAN H. W. SLAUSON:—The construction to which you refer is covered in Mr. Favary's paper by a short description.

M. C. HORINE:—I think Mr. Woods' point is that Mr. Favary did not cover what we call the banjo construction. A peculiar feature of construction is that the banjo is placed at an angle of 45 deg. instead of being vertical, as in an ordinary passenger-car axle; it inclines forward at the bottom. There are some very good reasons for that arrangement. First, it provides greater strength. We know that the shocks from the road are not vertical but, because of the forward motion of the vehicle and the shocks that are received from obstructions on the road, the forces acting on the axle are a combination of horizontal and vertical components which are resolved into an angular thrust. Of course, the strength of the banjo is greatest through it, instead of across it. Another advantage is the increased road-clearance. The revolving of the bottom portion of the banjo yoke toward the front raises it at the same time and, at 45 deg., it happens that the lowest portion of the banjo is just about on a line with the lowest portion of the large ring-gear or bull-gear. A further advantage that comes from the 45-deg. angle is that we are able to obtain greater top-clearance. Top clearance is becoming of greater importance, owing to motorbus development that requires a low flooring. Because of the second and third advantages, it is possible to use a larger size of banjo, a larger banjo-ring. This is one means of getting greater strength. Another advantage in the 45-deg. angle is that the spur-pinion or jack-shaft can be located anywhere that is convenient. This enables the bevel-pinion center to be located exactly at the height from the ground that the crankshaft occupies under full load, thereby securing a straight-line drive. This also has its effect on the universal action, because the nature of the deflection is a combination of fore-and-aft and angular deflections; so, we get approximately equal slip-joint and angular action as against a greater proportion of slip-joint action in a vertical banjo, and a very much greater angular deflection on the type of axle where the spur-pinion shaft is located immediately in front of the differential, therefore bringing the bevel pinion at a lower elevation.

The 45-deg. angle also greatly facilitates the removal and replacement of the carrier, which is sometimes necessary in double-reduction and worm-drive axles. If the banjo were horizontal, it would be necessary to lift the carrier vertically. There is usually a lack of top clearance under a truck body for this operation, which requires the removal of either the body or the axle from the truck. It is also difficult to line-up the banjo or axle-bowl studs with the holes in the carrier flange when the carrier must be lowered straight down. If it were vertical, as on passenger-car axles, the carrier would have to be drawn straight forward and the studs lined up by lifting vertically. This is even more difficult. The 45-deg. angle decreases the amount of vertical lift by half, and makes it possible to remove the carrier without disturbing the load, the body or the attachment of the axle to the chassis. In replacing it, the studs are lined up with the holes in the carrier flange without difficulty, since their angular relation permits them to be lined-up by merely swinging the unit.

Another effect of that arrangement is that the weight of the carrier is carried slightly ahead of the central line of the axle, thereby throwing the axle out of balance statically. That is of advantage because the driving or torque reaction tends to cause the axle to revolve backward. If it is out of balance in the forward direction, the two unbalances tend to neutralize each other and we get less torque-reaction on the spring, or on the torque-rod, than if the axle were in static balance.

It is worthy of note that the development in axle splines has shown the advantage of using the raised type as against the more conventional undercut type. It is well known that a spline, or any form of channel that is cut in a piece of steel, reduces its strength approximately to the strength of a section whose diameter is across the smallest part of the shaft. If the splines are raised over the diameter of the shaft, then the strength at the splines is increased.

We have assumed, thus far, that double-internal brakes are a good thing. But let us examine them for a moment. The reason we have two sets of brakes is to enable us to alternate them, thus allowing one set to cool-off when overheated while the other set is applied. It is the brake-lining that burns, but it is the drum that becomes incandescent. The brake-lining will cool-off almost instantly, but it takes time for the steel drum to cool. If the first set has heated the drum so hot that it burns the lining, applying a second brake to the same red-hot drum will not only prevent the drum from cooling-off, but will cause the second brake to burn almost immediately, whether it be side-by-side with the first set, on the other side of the same drum or in any other arrangement.

It is therefore desirable that the two sets of brakes act on entirely independent drums. On one type of axle described here in the paper, there are two drums, one within the other. The objection to this arrangement is that the necessarily restricted space makes it impossible to use brakeshoes sufficiently large for truck work. Furthermore, the inner drum is reduced to a diameter too small for effectiveness and is prevented from radiating its heat properly. The only thing left, therefore, is either a shaft-brake or a front-wheel brake. I think we are not prepared to change to front-wheel brakes; so, we have nothing left but the shaft-brake. In regard to the much maligned shaft-brake, it is not fair to criticize a construction because of the failure of certain examples of that construction. In some cases it has been used very successfully. A shaft-brake has the advantage that it is unaffected by the spring action. It is a very common experience with rear-wheel brakes that, when locked by the hand-lever when the truck is left unattended, spring action results in loosening the brakes. I had a car several years ago that had that defect. If I applied the brake while sitting in the car and then got out of it, the spring rebound would release the brake. It was then necessary to apply the brake two notches farther before it would hold the car on a grade. That is an extreme case, but it indicates the presence of such an effect. We know that motor-truck springs are much more affected by the load than those of passenger cars. The shaft-brake is the only one not affected by the spring deflection or the Hotchkiss-drive reaction; also, it is the only equalized brake possible because, while one may equalize the pressure applied to two brakes, one cannot equalize the traction of the two wheels on the road except through the differential.

MR. HERRESHOFF:—What was the foot-brake on the car Mr. Horine mentions?

MR. HORINE:—That shaft-brake was operated by the foot; I believe that is not the ideal way to operate a shaft-brake. I think the hand-lever is the proper means of application. That particular brake was improperly designed. It did not work well because it was really not on the frame of the vehicle; it was on the pinion housing of the axle. The result was that the reaction from the torque tended to release the brake. If a shaft-brake is mounted on the frame, one will not get any such effect. Much of the criticism of shaft-brakes is based on experience with types that were inclined to be savage or to chatter badly. Drivers of a number of cars that were equipped with this type habitually used the hand-lever, connected with the rear-wheel brakes in preference to the pedal operating the shaft-brake. The trouble with these brakes was that the drum and the shoes were improperly supported. The drum was usually secured to the tail-shaft of the transmission, so that it overhung the rear transmission-bearing, the shoes being supported separately by pins screwed into the transmission case. The result was that the drum did not run true and the shoes were deflected by the sudden strains put upon them. This had the effect of rapidly applying and releasing the brake. No wonder it chattered. These things cannot happen when the brake-drum is supported between two bearings, with a universal on either side and the entire brake assembly, including the bearings for the drum shaft, brakeshoes and actuating means are supported on one rigid carrier.

MR. MASURY:—Will Mr. Fielder describe the rear axle of the internal-gear type that is built for the Detroit buses?

MR. FIELDER:—The rear-axle construction of our type-L coaches, a number of which are operated by the Detroit Motorbus Co., is rather unconventional; for example:

(1) The carrying member is a heat-treated forged job. In this way we are able to obtain material with absolutely uniform properties and also there is a wide range of choice. Full advantage can be taken of alloy-steels and proper heat-treatment. Naturally, the use of high-grade material permits the use of minimum sectional or wall thicknesses, and this is a very important factor from the standpoint of weight reduction

(2) The ends of the carrying members are cranked, the wheel spindles being located above the drive-shaft center-line. This construction permits an extreme low level

(3) The design of banjo is such that it is inclined at an angle corresponding to the path through which the brake reactions must pass. In this manner the extreme fibers in the housing material are distributed in the direction of the greatest stresses

MR. MASURY:—Naturally, the Fifth Avenue Coach Co. is not limited by any particular type of axle. If it sees fit to give up one type of axle, it can use a built-up or a cast axle. It is interesting to hear from a company that is entirely unbiased as to the type of axle it builds or uses.

C. C. KEESLER:—Is it not true that the worm-gear drive lasts longer than any of the other types of axle that have been discussed?

MR. FAVARY:—I do not see why the double-reduction axle cannot be built to last just as long. I know of worm-gear axles that have given way soon and of others that have lasted a very long time. It simply depends upon the amount of pressure to which the worm is subjected; if the pressure is not excessive, the worm will wear a long time. If the pressure is excessive or if the lubrication should fail, the worm drive may be damaged within a very short time. Ordinarily, it does not fail in a short time.

FINLEY R. PORTER:—In discussing the difference between rear-wheel and propeller-shaft brakes, no stress seems to have been placed upon the relative amount of work performed by these two brakes. In trucking, where the loads are excessive, this should be a very important matter. I do not know why the propeller-shaft brake is not used extensively as a service brake instead of the rear-wheel brake.

MR. FAVARY:—There is no doubt that the propeller-shaft or transmission brake has a number of advantages. On the other hand, the disadvantages are that the torque is greater in the axle-shaft, as well as in the propeller-shaft and the gears; therefore, when a propeller-shaft brake is employed, heavier shafts and heavier gears must be used to obtain the same factor of safety and hence the construction will be more expensive. Regarding the difficulties experienced by Mr. Horine with wheel brakes, if the brake linkage is correctly designed these objections are practically overcome.

MR. MYERS:—I do not want to be interpreted as wishing to add weight to unsprung parts. Everyone strives to reduce the weight of the axle parts to a minimum; that is very important. But I do wish to reiterate that the matter of tire wear being in proportion to the unsprung weight has by no means been proved. There are varying conditions in almost every case which entirely nullify any data that I have ever seen on this subject.

In regard to the tire mileage on wood wheels as compared with that on steel wheels, the test on unsprung weight that I referred to was really to check-up the advantage of one wheel over another. We used four trucks to get an average of 24 tires. We put a wood wheel at the right side of one truck in the front and at the left side in the rear. On another truck, we put the wood wheel over on the other side, so that each front axle had a wood wheel and a steel wheel. The entire advantage in winter and summer performance was about 15 per cent in favor of the tires on the wood wheels over those on the steel wheels.

MR. FIELDER:—We have had tires from the same tire company some of which were returned for credit because of not doing their guaranteed mileage, but others in the same batch would do five times their guaranteed mileage. One cannot tell whether a tire is cured properly or not. It may be that different qualities of tire were used in the tests Mr. Myers mentions.

MR. MYERS:—The tires were all made at about the same time from the same batch and received the same curing. They were inspected carefully; the comparison was so close that we could not detect any difference. I will admit that there may have been some differences in the tires, but we took care to minimize them. It is remarkable that the rate of wear on each truck was different, and the rate of wear on the four tires on each truck was grouped, showing that the tires must have been very nearly of the same composition.

MR. HORINE:—From that test we may at least assume that Mr. Fielder's mileage experience with tires was not very much affected by whether the wheels were wood or steel; so, the decreased unsprung weight must be the explanation of the better tire wear one gets on the lighter axle.

MR. MYERS:—But the results show that there was less tire wear on the axles with the greater unsprung weight.

MAURICE WALTER:—The wood wheels are probably much different in weight compared with the steel wheels, and their inertia effect is probably enough greater to give an unbalanced differential action. In the ordinary truck there is a certain differential action, but if one wheel has a greater inertia than the other, there will be an unequal differential action and the tire wear will be entirely different from that of normal conditions.

MR. FAVARY:—Inasmuch as Mr. Myers agrees that it has not yet been proved or disproved in practice that a light unsprung weight is favorable, which I maintain, I think we ought to assume that the theoretical proofs are correct until practice proves them incorrect; that is, a lighter unsprung weight is more favorable.

MR. MYERS:—I cannot accept that, because such evidence as I have obtained is contrary to it and I prefer evidence to theory.

MR. HORINE:—Mr. Rockwell mentioned the proportions of worm-drive and double reduction axles in use in England and prefaced his remarks by saying, "Disregarding the chain drive." I think it is not fair to disregard the chain drive in England. They have been building trucks longer than we have and they redesign their trucks more frequently than we do. It is very interesting to notice the number of new heavy-capacity trucks in England, post-war models, that have been brought out with chain drives. The chain drive is on the increase in England.

In regard to the quietness of the worm drive, it has been said again and again that a quiet machine is an efficient one, and that friction always produces noise. That is a fallacy which is accepted at face value and in many cases without question. Yet a worm-drive axle is always quiet, whether it is producing friction or not. I have seen worm-drive axles so badly bound-up in their bearings and on their worm surfaces that they would stall the engine, and still they were quiet. The chain drive is very much maligned because it is noisy. I believe that the noise of the chain drive is one of its greatest virtues, because it tells a story. Ingenious inventors develop devices to notify us that certain parts require attention. A chain drive is an inherent alarm. Under proper conditions, it makes some noise, but when it becomes worn or out of adjustment to a dangerous extent it gives an audible warning which the worm drive does not give. That warning is sufficiently in advance, in many cases, that it is perfectly safe to run for two weeks or more with the chains in that condition, and one can change the chains or sprockets at his convenience.

Much of the present conception of the chain drive is based upon past experience. Most of our manufacturers have not had any recent experience with the chain drive and, while they have been developing various other types of drive, the development of chain drives has gone on and some very genuine improvements have been made. Among them are case-hardened front sprockets, very much larger sprockets, more moderate reductions in the chains and better radius-rod construction. Radius-rods that are attached to frame fittings instead of to jackshafts and radius-rods that are in line with chain centers and therefore give less chance for springing the axle and jackshaft together have been adopted.

Concerning bevel-gear reductions, Mr. Favary has specified 6 to 1 as a limit in the present state of the art. It is possible to get a very much lower reduction than that, but it also is a fact that the amount of gear reduction one can get depends upon the amount of load that is being transmitted through these gears; the greater that load is, the less reduction one can use because of the physical limitation of size that the vehicle imposes. It is fair to say that on a very heavy truck the maximum is 4 to 1, and on a light passenger-car one might use a greater reduction than 6 to 1.

MR. FIELDER:—What mileage can be expected from the rear-wheel driving-chains? And what is the cost of replacing the chains? It seems to me that chains exposed to the grit and dirt of the roadway could not last very long.

MR. HORINE:—Normal chain-drive mileage is somewhere between 18,000 and 21,000 miles in regard to the life of the chains. The life of case-hardened front-sprockets is approximately twice that of the chain. The rear sprockets never wear out. The front sprocket can be reversed at the time of the first chain renewal. The cost of a chain is as much as $85 for a large truck. In comparing the cost of chain replacements, it should be borne in mind that the age of the truck has nothing to do with it. The cost of worm replacement during the period of truck life is along a curve that has its progression from left to right and moves upward.

C. W. SPICER:—The extra weight or extra strength required with the propeller-shaft brake has been cited against it. That is properly justifiable in theory. However, after fifteen years of specializing in propeller-shafts, I cannot say that, in practice, there is any more evidence of wear in the propeller-shaft when the transmission brake is used than when there is none.

MR. FAVARY:—Does Mr. Spicer refer to light cars and trucks, or to heavier trucks?

MR. SPICER:—I refer to either size.

MR. FAVARY:—Then I disagree with Mr. Spicer, because we find in the example I have taken that if a propeller-shaft brake had been used, the maximum torque due to braking would have been about 97,000 lb. in., whereas that due to the engine is about 65,000 or 66,000 lb.-in.

MR. SPICER:—The maximum-torque stress on the propeller-shaft due to the transmission brake is that which is required to slip the tires on the road. The shafts should be designed to slip the driving-wheels under any condition. The total number of hours of life of a car during which load is applied to the propeller-shaft through the transmission brake is so small and the periods of application are so short that the reduction in the life of a properly designed propeller-shaft due to transmission braking has been found to be negligible. My comments are based entirely on long experience rather than on theory.

MR. FAVARY:—I cannot see how the dropping of a full-floating axle into a hole can make much difference in regard to the torque. I still maintain that a transmission brake will put a higher torque on the shafts in heavy trucks. We find in practice that it is not possible in heavy trucks to slip the wheels with the engine power on dry roads; whereas, when a propeller-shaft brake is employed, the torque created from the slippage of the wheels is considerably higher than that arising from the engine.

MR. MASURY:—I think Mr. Favary and Mr. Spicer are both correct. The real difficulty with propeller-shaft brakes is not with the brake itself but with the element of allowing a dead or a nearly dead engine to be picked-up by the car's momentum. This occurs in trucks and large cars after driving down a long hill. The car gains considerable speed and the drive-shaft is running very fast; the energy necessary to accelerate the engine often throws out the drive-shaft. This is far in excess of any

strains which may be imposed on the propeller-shaft by a propeller-shaft brake. I believe that the great advantage of the equal distribution through the differential and the rear axle of a breaking effort, far overcomes any disadvantage. It also leaves the brake-drums on the rear wheels much less work to do and relieves the "spinning-out" action and the heat distribution.

The great difficulty I have had with propeller-shaft brakes was due to their being improperly designed. Since we reached the point where we encased the brake mechanism in a frame, put bearings on the outside of it and had the brakeshoes properly disposed, the propeller-shaft brake certainly has been very successful. It is much better than the other types in getting rid of the heat from the break-drum. When you get down a long hill, your brakes will be so hot that you can spin them out-of-round. It is a question of not letting those brake-drums get warm, so they cannot distort with the heat and with the spinning action of the brakeshoe.

I would like to bring up the question of torsion shafts on the rear axle. The particular shaft I have in mind can be twisted around three times. We have attached considerable importance to the fact that the propeller-shaft can move around in torsion. As was pointed out, the greatest strain is torsional and, if we use this as a spring, we soften down the action of the drive and the propeller-shaft brake, which cannot be done in a semi-floating axle, because it will not be possible for it to get into a torsional action. One of the great things in favor of the full-floating axle is that the propeller-shaft is alive.

STANDARDS ADOPTED BY LETTER BALLOT

THE proposed standards and recommended practices printed on pp. 565 to 585 inclusive of the June, 1923, issue of THE JOURNAL and approved at the Standards Committee Meeting at Spring Lake, N. J., June 19, were approved by the Society members by the letter ballot that closed on July 23. The new and revised data sheets containing the recommendations approved were mailed to the members during August, practically within 2 months of the time they were approved by the Standards Committee and more than a month earlier than former issues have been mailed. This was due to the fact that the revision in the Standards Committee Regulations requiring the letter ballots to be canvassed 3 weeks after publication of the Standards Committee action in THE JOURNAL, instead of 2 months after the Society Meeting, was authorized by the Council at Spring Lake.

The complete vote of all the recommendations balloted upon is recorded in the accompanying table. The first column gives the number of affirmative votes cast; the second column, the number of negative votes and the third column, the number of members who did not vote either way.

Subject	*Yes*	*No*	*Not Voting*
Tractor Belts and Pulleys	84	0	218
Front Wheel Mountings	123	3	176
Tenon Holes for Steel Felloes	109	2	191
Metric-Type Thrust Ball-Bearings	142	9	151
Metric-Type Roller Bearings	145	5	152
Shaft and Housing Fits and Tolerances for Ball Bearings	155	5	142
Rubber Bushings	145	1	156
Clips	151	0	151
Cable Terminals	153	0	149
Starting-Motor Mountings	149	1	152
Battery Trays for Electric Trucks	74	0	228
Charging-Plugs and Receptacles	74	0	228
Electric Vehicle Motors	69	0	232
Carbureter Flanges	153	1	148
Passenger-Car Frames	129	0	173
Iron and Steel Specifications Part IX	184	2	116
Iron and Steel Specifications Part X	182	2	118
Bases, Sockets and Connectors	135	1	166
Radiator Nomenclature	144	0	158
Brake-Lining	152	1	149
Rod-End Pins	153	1	148
Cotter-Pins	168	0	134
Felt Specifications	140	1	161
License-Plates and Brackets	156	0	146
Taper-Fittings with Plain or Slotted Nuts	158	0	144
Motor-Truck Cabs	93	2	207
Stationary-Engine Crankshafts	76	0	226
Stationary-Engine Belt-Speeds	74	0	228

FIRE HAZARDS OF AUTOMOBILES

IN writing on this subject in a recent issue of the *Eastern Underwriter*, G. D. Becker, assistant engineer in the casualty department of the Underwriters' Laboratories, points out that in analyzing the inherent hazards of an automobile when considered under general groups that can be applied to any automobile, several main items must be given attention. These are the storage of fuel, the fuel-feed system, the fuel line and fittings, carburetion, electrical equipment, the exhaust system and miscellaneous items. The method employed by the Underwriters' Laboratories in analyzing automobiles from the fire hazard viewpoint is outlined below.

STORAGE OF FUEL

Capacity of Tanks.—Not less than 10 gal. nor more than 35 gal.

Location of Tank.—At rear of car and not enclosed in body

Construction of Tank.—Strength of materials and design of tank

Tank Mounting.—Mounted to prevent chafing and excessive wearing of frame being transmitted to tank

FUEL-FEED SYSTEM

Gravity.—Pressure-release valve provided

Pressure.—Construction of vacuum tank

Vacuum.—Location of vacuum tank

FUEL LINE AND FITTINGS

Tubing and Connectors.—Tubing annealed, seamless and "non-corroding" material
Tubing suitably secured at all points to prevent chafing and protected from injury
Feed line above road clearance

Gages and Reserve.—Quantity indicator of suitable type provided and correctly installed
Reserve section provided in main supply tank

Shut-Offs.—Shut-off valve provided to shut off supply of fuel from storage or vacuum tank to carbureter.
Shut-off operable from driving compartment

CARBURETION

Design of Carbureter.—Eliminating excessive back-fire due to improper carbureter design

Location of Carbureter.—Located remote from spark or flame emitting devices
Use of suitable air-horn to arrest back-fire flame

Provision For Drainage—Carbureter provided with attachment to insure direct drainage of over-flow gasoline to ground without traps or similar hazards

ELECTRICAL EQUIPMENT

Wiring Materials.—High-tension wires provided with proper insulation
Low-tension wires provided with proper insulation
Low-tension wires of ample copper capacity and mechanical strength to carry current load

Wiring Connectors.—Splices made in workmanlike manner and suitably protected
Terminal connections used on all wires

Wiring Supports.—All wires supported at frequent points to avoid drooping, chafing and excess vibration

Wiring Protection.—From mechanical injury
Damage to insulation from heat
Exposed to accumulation of grease, oil or gasoline

Devices.—Instruments and devices of suitable design
Fuses or other automatic overload protective devices used in low-tension circuits

Circuits.—Provision for inspection lamp circuit
Ignition system not of multiple spark-plug type

EXHAUST SYSTEM

Position.—Exhaust pipe and muffler above road clearance
Exhaust-pipe clearance from fuel tank and combustible materials
Exhaust not exposed to accumulation of grease, oil or drippings

Muffler and Cut-Out.—No cut-out used; if used, not operable from driving compartment
Discharge of exhaust directed away from combustible material
Muffler and connections installed in workmanlike manner
Muffler sufficiently strong to withstand internal explosions and not heat beyond reasonable point

Exhaust Heater.—Exhaust heater properly installed, avoiding excessive temperature rise in surrounding materials

MISCELLANEOUS

Mud Pan Construction
Horizontal Side Plates
Vertical Side Plates

The testing of the individual units that are used in automobile construction is very essential in order that the hazards may be reduced to a minimum. In the outline mention is made of the strength of the muffler to resist internal explosions. This is determined by mounting the muffler on a standard test block and subjecting it to repeated explosions. When the test is completed an examination of the muffler is made to ascertain the extent of the damage and the distortions. The head and the longitudinal seams must be intact and the baffles and the inner shells must not have become distorted to such an extent as to allow the hot exhaust gases to come in contact with combustible materials. Similar tests are made on all units, such as the carbureters; vacuum tanks; ignition, starting and lighting systems; exhaust heaters and numerous accessory devices. To minimize the inherent fire hazard incident to the design and construction of automobiles, the Underwriters' Laboratories at the request of an automobile company will send an engineer to the plant to analyze the vehicle according to the specifications printed above. The hazards that may ultimately cause a fire as shown by long experience, extensive tests and careful research are noted and recommendations for changes in the design are made. Usually these recommendations, such as additional supports for the fuel line and the wiring system or changing the exhaust manifold casting to give a greater clearance between the exhaust pipe and the toe-board involve only a slight increase in the cost.

In addition to examining automobiles at factories the fire hazards of accessory equipment should be minimized as much as practicable. Among the accessory devices received by the Underwriters' Laboratories for testing are engine heaters, heaters that employ exposed sparks and use gasoline for fuel, electric carbureters, manifold heaters and the like. When a device is submitted for examination and test a plan of investigation is drawn up to consider the extreme conditions under which the device may present a serious fire hazard. Tests are then conducted and the manufacturer's attention is called to features of the device that may have a bearing not only upon fire hazard but also upon the accident, collision and theft hazards.

Research Topics and Suggestions

THE Research Department plans to present under this heading each month a topic that is pertinent to the general field of automotive research, and is either of special interest to some group of the Society membership or related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing-house for research information, we shall be pleased to receive the comments of members regarding the topics so presented, and their suggestions as to what might be of interest in this connection.

BUREAU OF PUBLIC ROADS HIGHWAY TESTS

HIGHWAY research and the closely related problems of automobile transportation are now attracting a lively interest among engineers. At the open session of the Society's Highways Committee, held during the Summer Meeting, a large number of our members discussed very profitably the program of highway research initiated by the Bureau of Public Roads and planned as a cooperative project in which our Society, the National Automobile Chamber of Commerce, the National Research Council, the Post Office Department and the Rubber Association of America were invited to assist. Since this meeting at Spring Lake, N. J., the tentative plans have been perfected and the preliminary arrangements have progressed so far that actual tests are now under way.

The tests are being conducted at the Arlington (Va.) Experimental Farm of the Department of Agriculture where a series of concrete test-slabs, varying in thickness from 4 to 10 in., have been laid on three different types of subgrade, the latter having been chosen to represent extreme and average conditions. A number of trucks of different capacities and tire equipment have been chosen for use in the work.

The tests will embrace an extensive series of runs over the test-slabs with the trucks under various conditions of load and speed and with obstructions arranged and proportioned so as to simulate, as nearly as possible, actual service conditions; these conditions will be determined by making preliminary runs over a road whose roughness may be considered as typical. During these preliminary runs, an accelerometer suitably mounted upon the truck will give indications from which typical maximum-impact conditions can be determined and later duplicated upon the test-slabs by arranging the obstructions so as to produce equivalent impact-forces. The effect of these forces upon the road will be determined by strain gages mounted at various locations in the slabs.

It is hoped that the results of these tests, which will probably require more than a year to complete, will be of value not only to the highway engineer but as well to the designer and manufacturer of automobiles, tire and wheel equipment, etc. Furthermore, the outcome of the tests should prove to be of considerable importance in supplying a rational basis for future highway legislation.

The Society is keeping in close touch with the tests through its Highways Committee, the Truck Division of the Standards Committee and its Research Department.

MOTION AND FORCES BETWEEN WHEEL AND ROAD

A discussion of the motion and forces obtaining between the wheel of an automobile and the road appeared on p. 171 of the August issue of THE JOURNAL. This material was in the nature of a preliminary analysis and introduction to a paper by Dr. B. J. Babbitt of the Bureau of Standards in which the problem is treated mathematically. As announced in that issue of THE JOURNAL, it was hoped that this paper would be ready for presentation this month, but owing to an unforeseen delay we find it impossible to print the paper at this time. It will, however, appear in the near future.

GEAR-GRINDING AND TOOTH-FORMS

IN the paper bearing this title that was presented by Glenn Muffly at the March meeting of the Detroit Section and printed in the June issue of THE JOURNAL, a number of errors crept in. Some of these were typographical and others were due to mistakes or lack of clearness in the copy that was supplied by the author. While these errors will all be corrected when the paper is printed in the TRANSACTIONS, they are listed below so that members who desire to do so can correct the paper in their copies of THE JOURNAL.

p. 545—In the third line from the end of the second paragraph of the abstract "gear cutting" should read "gear grinding"

p. 546—The triangle at the left should have the right angle adjacent to the side marked "cosine" instead of opposite to it

p. 547—In the third line above Fig. 6 "*l*" should be "1"
In the caption of Fig. 8 "hobbing" should be changed to "rack tooth"

p. 548—The left side of the tooth profile at the left of Fig. 11 should appear as a series of flat spots and not a smooth curve
In the line above Fig. 12 "two" should be changed to "four"
In the caption of Fig. 12 the words "carrying the grinding wheel" in the second line should be omitted

p. 549—In the caption of Fig. 17 "depth" should be changed to "width"

p. 552—The pressure angle value of "18 deg. 37 min." which occurs in the last two paragraphs in the second column should be "16 deg. 44 min."

p. 553—In the sixth line from the top and in next to the last line in the first column the angle should be "16 deg. 44 min." and not "18 deg. 37 min." as printed
In Fig. 24 the term "pitch angle" that appears four times in the central gear and once in each of the three other gears should read "pressure angle"
The steel tapes connecting the two base-circle discs in Fig. 25 cannot be seen. In each of the five views these tapes can be shown by drawing two lines tangent to the two circles and crossing each other like the base circle tangents do in Figs. 5 and 6. These tapes act as crossed belts causing the two discs to rotate at equal periph-

(*Concluded on p. 249*)

Automobile Head-Lamp Regulation

By JAMES J. SHANLEY[1]

SEMI-ANNUAL MEETING PAPER

THE author outlines the present status of state regulation of automobile head-lamps and head-lamp devices as practised by the State of New Jersey. The 1922 Report of the Committee on Motor-Vehicle Lighting of the Illuminating Engineering Society was used as a basis, and the adoption of its recommendations was begun then.

The Commissioner of Motor Vehicles of New Jersey was instrumental, about 1921, in forming a Conference of Motor-Vehicle Administrators to hold quarterly meetings, its members including the administrators of 10 states who pledged themselves to secure the necessary legislation in their respective states to have these regulations put into effect. Later, out of about 200 devices considered, the committee recommended 22 that met the standard, and the conference adopted this list as constituting "approved" head-lamp devices in April, 1923.

NEW JERSEY was one of the pioneer States in the regulation of glare from automobile head-lamps but, previous to 1923, we in New Jersey were more concerned about the elimination of glare than we have been about the actual amount of driving light available to a driver.

When the Department of Motor Vehicles took up this problem some years ago, many of the devices on the market that were intended to eliminate glare were very crude. The department approved for use many of these devices on the theory that almost anything that diffused or broke-up the beam of light was preferable to the use of a naked reflector. However, when the 1922 Report of the Committee on Motor-Vehicle Lighting of the Illuminating Engineering Society became available to us, we changed our viewpoint and began to adopt measures to conform to its recommendations. Incidentally, the authority of Motor Vehicles Commissioner Dill under our present statute is such that no additional legislation was necessary.

Commissioner Dill was instrumental about 2 years ago in forming the Conference of Motor-Vehicle Administrators with the officials of the following States as members: Maine, Vermont, New Hampshire, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Maryland and Ohio. Commissioner Dill of New Jersey is president of this conference, which holds quarterly meetings; one of its objects is the securing of uniform automobile laws in the neighboring member States.

At the April, 1922, meeting of this conference, the head-lamp situation was taken up and, at the July, 1922, meeting, the conference adopted the 1922 specifications of the Illuminating Engineering Society as a standard for the approval of head-lamp devices. The members of the conference pledged themselves to secure the necessary legislation in their respective States to put these regulations into effect.

At this July, 1922, meeting, the conference also appointed a special head-lamp committee to examine head-lamp devices and to recommend to the conference which devices to approve and which to reject as not conforming to the 1922 Standard of the Illuminating Engineering Society. After much preliminary work, this special committee held two all-day sessions in February, 1923, at the Electrical Testing Laboratories, New York City, and two sessions at Hartford, Conn., in April, 1923. This committee drew up a composite list of all devices approved in any of the member States and then proceeded to consider every device that used the Illuminating Engineering Society's 1922 Specifications as a standard. Out of almost 200 devices considered, the committee found about 22 that, in its opinion, met the standard. The committee recommended these devices to the conference at its April, 1923, meeting at Hartford, and the conference adopted the committee list as approved devices.

The member States of the conference are now making this list official as quickly as the statutes of the various States will permit. Commissioner Dill, of New Jersey, has ordered these regulations into effect in New Jersey on July 1, 1923. He realizes that the mere use of approved devices will avail nothing unless these devices are installed properly. He is now working out a system of stations under department supervision where car-owners can have their head-lamps aimed and focused properly.

It has come to Commissioner Dill's notice recently that many head-lamp devices on well-known cars are installed improperly or carelessly when leaving the factory, and he respectfully asks the cooperation of automotive engineers who are engaged actively in car production in securing proper head-lamp installation, to the end that the menace of glaring lights be removed from our highways.

[1] Inspector, department of motor vehicles, State of New Jersey, Trenton, N. J.

GEAR-GRINDING AND TOOTH-FORMS

(*Concluded from p.* 248)

eral speeds in opposite directions. The point at which the tapes cross establishes the pitch diameter for each gear

p. 558—In the 22nd line from the bottom of the first column "a_2" should be changed to "e"; in the 19th line "b_2" should be changed to "f"; in the 18th line "b_1" should be changed to "c" and "a_1" should be changed to "b"; in the 16th line "a_1" should be changed to "b" and in the 15th line "b_1" should be changed to "c." In the 19th line from the bottom of the second column "Fig. 5" should be changed to "Fig. 3," and in the 16th line "the tangent tt" should have read "the tantangent tt_1"

SOCIETY MEETINGS

CLEVELANDERS VISIT TIRE FACTORY

Air-Cushion Tires Demonstrated and Their Effect on Car Performance Discussed

J. E. Hale

Journeys afar seem to be a specialty of the Cleveland Section. Akron, capital of rubberdom, was the destination of its latest pilgrimage on Aug. 17 when some 50 members enjoyed the hospitality of the Firestone Tire & Rubber Co. James E. Hale, exponent of doughnut tires, who acted as chief host, read a paper on the qualities of monster pneumatic tires, which are formally, but less generally, known as air-cushion tires. All the Firestone factory buildings were inspected during the visit. Golf in the morning and a dinner with cabaret trimmings in the evening were included in the day's diversified program.

Soon after arriving, the visitors assembled at the Portage Country Club, where they learned that an 18-hole handicap golf tournament had been arranged for their entertainment. Rivalry was intensified by the broadcasting of the news that an unblemished cord tire awaited the member whose skill or handicap enabled him to turn in the lowest net score. This prize went to G. W. Carlson whose generous handicap of 40 reduced his net score to 69. Dan Swander was a close second with 71, net. R. S. Leonard recorded the low gross score of 85, which is fair shooting among friends. One partly used tube of tire cement was presented to A. J. Scaife for the unusual feat of accumulating 150 strokes in a mere 18 holes and in a half-day's play!

After a palatable lunch at the Firestone Club, the visitors were loaded into cars of sundry and divers makes, all of which were equipped with air-cushion tires. The first stop was at the Firestone rim plant where clincher and straight-side rims were seen in process of manufacture. Flat strip-stock enters at the end of a one-story building and is rolled into circular form, the ends are butt-welded electrically, and the basic rim is then ready to start on its way past rolls, punches and inspectors. Cleaning and plating are done automatically by chain conveyors that carry the rims through cleansing solutions, plating tanks and dryers to the calloused hands of the car loader, who waits impatiently at the end of the last chute. Gravity and the circular shape of the rims solve all conveyor problems; the passage from operation to operation is just one roller-coaster after another. This is material handling reduced to its simplest form.

Wire-braiding machines, the bobbins of which chase one another about on a surface plate like skaters cutting graceful figure 8's on the ice, fascinated the members who saw them in the rim plant. Flat braided wire is used as the foundation for tire beads, the footage consumed daily reaching large figures.

Passing on to the tire plants, the visitors were shown the highly developed unit devoted to building 30 x 3½-in. clincher tires exclusively. Huge continuous calender machines, rolls that spat tread strips resembling the licorice sticks of our youthful days, the making of inner tubes, tire-building machines, tall steam-curing cylinders and interesting automatic machines and conveyors too numerous to mention were passed in rapid succession. Each step in the tire-building process was explained by men familiar with the details of every operation. Thorough inspection was also made of the expansive plant devoted to manufacturing tires of the larger sizes. Weary of limb, but possessing a complete picture of tire and rim manufacture, the members assembled in the Firestone auditorium.

Previous to the technical meeting, demonstrating cars transported the visitors over a route that traversed railroad and street-car tracks, the brick pavement being dotted with chuck-holes and other irregularities conducive to the riders' discomfort. The air-cushion tires rolled smoothly over these obstacles and convinced the passengers that a distinct improvement in ease of riding had been accomplished. Mr. Hale presented substantially the same technical paper that made such a favorable impression at the Semi-Annual Meeting. This paper was printed on p. 41 of The Journal for

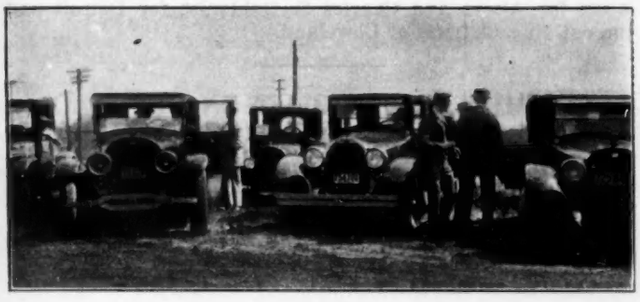
Sections Secretaries

Buffalo Section—J. W. White, 1700 Elmwood Avenue, Buffalo
Cleveland Section—L. L. Williams, 1051 Lake View Road, Cleveland
Dayton Section—Ernest Dickey, Delco-Light Co., Dayton, Ohio
Detroit Section—K. L. Herrmann, 416 Capitol Theater Building, Detroit
Indiana Section—George T. Briggs, Wheeler-Schebler Carburetor Co., Indianapolis
Metropolitan Section—F. H. Dutcher, Columbia University, 117th Street and Broadway, New York City
Mid-West Section—H. O. K. Meister, 111 West Washington Street, Chicago
Minneapolis Section—Phil N. Overman, 10 South 10th Street, Minneapolis
New England Section—V. A. Nielsen, 701 Beacon Street, Boston
Pennsylvania Section—A. Ludlow Clayden, Sun Oil Co., Philadelphia
Washington Section—C. H. Young, 724 Ninth Street, North West, City of Washington

July, the comments made in the discussion being reported briefly on p. 67 of the same issue and in full on p. 213 of this issue. The effects on car operation were treated fully and included such topics as car speed, steering ability, front-wheel shimmy, traction, braking control, punctures, blow-outs, and side-sway.

Leaving the aroma of smoldering rubber and the din of machinery, the pilgrims returned to the Portage Country Club where their ravenous appetites were appeased by a sumptuous "spread" set by the Firestone hosts. Such delicacies as steam-cured duck, gum-dipped olives, para biscuits and caucho balls in latex were announced on the menu, but the chef, being a non-member of the rubber ring, bounced dishes of greater appeal off the stove. Thence followed a chirping and colorful cabaret accompanied by vocal excesses on the part of the assembly. Preference ran to the following version of the banana anthem:

Yes, we have no balloon tires; we have no balloon tires today.
"Doughnuts" we don't make 'em.
Who is there would take 'em?
And too many balloons "blow" away.
We've low pressure Air Cushion Ti-ers!
All triers are buyers—
But Yes! we have no "balloon" tires; we call them "Air Cushion" today.



FLEET OF CARS THAT TRANSPORTED AKRON VISITORS ON LOW-PRESSURE AIR

In closing these impressions of a successful meeting, it is fitting to record that a vote of thanks was extended to the officials of the Firestone Tire & Rubber Co. for their hospitality. Technical talk, educational factory-inspection, sports and entertainment were mixed in the proper proportions, so that all who attended the meeting felt fully repaid for the time taken from business duties.

NASH MOTORS WILL WELCOME MID-WEST

Cleveland is not the only Section to include a plant inspection in its year's program. On Sept. 21, the Mid-West Section will spend the day at the Nash plant in Kenosha, Wis. The morning will be devoted to golf, followed by an afternoon in the Nash plant and a dinner closed with informal speeches.

Prescott Ritchie is chairman of the Program Committee that has provided this get-together to begin the year.

CUTTING OPERATING COSTS IN TWO

John F. Duby Believes Proper Wheel Alignment Can Effect Big Savings

When John F. Duby of the John F. Duby Co. addresses the New England Section at its September meeting he will be prepared to show how the cost of operating a car can be reduced from 5 to 50 per cent by merely using the often-overlooked adjustment already on the tie-rod.

Mr. Duby has worked out a short, easy method of calculating the correct setting to insure good steering with the least possible tire-wear. He has made a very thorough study of wheel alignment and is ready to answer any question on it.

Correct alignment will be discussed in detail and the effects of axles, tie-rods, king pins, radius-rods, steering-arms, steering gears and spring-suspension will be taken up separately. Both front and rear wheels will come in for close study. Methods of testing rear wheels and axles for accuracy and the usual causes of their misalignment will be studied in detail. Front wheels will be treated as completely. Toe-in and camber are also to be thoroughly discussed.

The meeting will be held at the Hotel Buckminster, Boston, on Sept. 11, beginning promptly at 8 p. m. It is surely unnecessary to point out the value of the meeting to Society members in the New England Section's territory.

Committee-work in the New England Section is in charge of the following: Papers, I. D. Shaw; Membership, Harry Fosdick; Meetings and Entertainment, Linwood H. Young; and Publication, James A. Moyer.

RECREATION MEETING IN DETROIT

Section Opens Season with Social Meeting at Detroit Boat Club

Believing that good-fellowship is conducive to successful professional activity, the Detroit Section will open its year of meetings with a social gathering at the Detroit Boat Club on Monday, Sept. 10. Swimming and canoe races will start the program at 4:30 in the afternoon. A war canoe race will be contested between two crews each consisting of 20 members. Diving contests will enable the more sylphlike geniuses of motordom to display their dexterity from the high board.

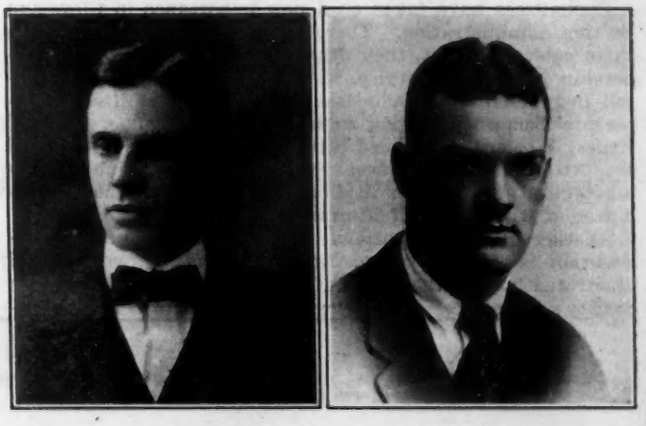
Dinner will be served at 6:15 and dancing will follow until 11 o'clock. There will be no speeches, technics or mathematical debates; the occasion is simply an informal social gathering of members, their wives and sweethearts. Tickets are priced at $3 and should be purchased in advance at the Section office, 416 Capitol Theater Building, Detroit.

Detroit Section meetings will be well advertised this year by a Publicity Committee under the direction of W. B. Stout. Other Detroit Section committees and their chairmen are: Meetings, George L. McCain; Membership, Harry Knepper; and Entertainment and Reception, H. M. Rugg.

ADJUSTMENT CRUX OF LAMP PROBLEM

Unusual Demonstration to Be a Feature of Metropolitan Section Meeting

R. N. Falge, of the National Lamp Works of General Electric Co., has demonstrated that the proper adjustment of



C. B. Veal, Treasurer F. H. Dutcher, Secretary

TWO OF THE METROPOLITAN SECTION OFFICERS FOR THE COMING YEAR

Schedule of Sections Meetings

SEPTEMBER

10—DETROIT SECTION—Dinner, dance and water sports
11—NEW ENGLAND SECTION—Wheel Alignment—John F. Duby
17—CLEVELAND SECTION—The Single-Eight and Its Merits—J. G. Vincent
20—METROPOLITAN SECTION—Headlights—R. N. Falge
21—MID-WEST SECTION—Inspection of Nash plant, Kenosha, Wis.

head-lamps already in use will solve many of the motorist's lighting problems. Better road illumination, the prevention of objectionable glare and the securing of a better and a safer head-lamp all depend on the adjustment that will provide the most effective distribution of light.

Mr. Falge is prepared to do more than describe the type of lens necessary and list the requirements for uniform and satisfactory lamp-service to do away with the difficulties of focusing. He will bring a real car into the meeting-room for a practical demonstration of better head-lamps and their proper adjustment.

Members of the Metropolitan Section who missed Mr. Falge's talk at Spring Lake will be able to hear it with the addition of new material at the meeting on Sept. 20 at the Automobile Club of America, 254 West 54th Street, New York City. The meeting, which is scheduled for 8 o'clock, will be preceded by a dinner at 6:30 p. m.

Metropolitan Section committee-chairmen are: C. B. Veal, Meetings; J. W. Lord, Membership; and A. C. Bergmann, Reception.

EIGHT-IN-LINE ENGINES

Subject of Paper by J. G. Vincent at Cleveland Section Meeting This Month

J. G. Vincent, past-president of the Society and head of the Packard engineering staff, will be the speaker at the Cleveland Section Meeting, Sept. 17. Eight-in-line engines and four-wheel brakes will be the subject of Mr. Vincent's talk. Engineering information of unusual value will be presented and a lively discussion is anticipated because of the general interest in the topic of the paper. Cleveland Section meetings are held in the Cleveland Hotel starting at 8 o'clock and are preceded by an informal supper and social get-together. All members of the Society are welcome.

CLEVELAND SECTION COMMITTEES

Committees have taken on a new importance in Cleveland Section administration. There are more of them and, with their sub-committees, they draw a larger part of the membership into actual service. The Program Committee, Russell Begg, chairman, includes a House Sub-Committee; Membership Committee duties, under the general supervision of Ernest Wooler, are divided between the main committee and the Attendance and Guest Sub-Committees. Publicity is taken care of by a sub-division of the Entertainment Committee of which K. B. Britton is chairman.

Another of the innovations introduced by the new administration is *The Cleveland Junior Journal*, a well-printed illustrated booklet that looks like a miniature edition of the Society's JOURNAL. Its purpose is to keep its readers well-informed on Cleveland Section affairs. Past meetings are reported and coming meetings announced in a way to draw a maximum attendance. A schedule for the whole year's program is published and suggestions are not only sought but made easy by a coupon to be sent to the Secretary. The Junior Journal also offers very practical assistance in a supplementary Employment Service. Seven men have been placed so far through this medium.

Cleveland is solving the problem of reaching members outside of Cleveland by the activities of a special Out-of-Town Committee: T. V. Buckwalter for Canton, Walter H. Allen for Akron and Charles S. Dahlquist for Detroit and the outlying districts of Cleveland.

COMMITTEE CHAIRMEN IN BUFFALO

The officers of the Buffalo Section share their responsibilities with two committees, one on Papers and Entertainment, the other on Public Relations. The chairman of the first is H. T. Youngren; of the second, J. G. Willet.

There will be no meeting of the Buffalo Section in September.

DAYTON'S SPECIAL COMMITTEE

Besides the usual committees on Membership, Entertainment, and Program, the Dayton Section has a special committee to award the Wright Brothers Medal. The chairmen of the Dayton committees, in the order given, are R. V. Hutchinson, Luzern Custer, George E. A. Hallett and J. H. Hunt.

The Dayton Section will not hold a meeting in September.

WELCOME READY AT INDIANA MEETINGS

Members and guests of the Indiana Section will be made to feel at home at every meeting by a Reception Committee headed by B. F. Kelly. William Guy Wall is responsible for the Papers and Meetings Committee and Charles A. Trask is chairman of the Membership Committee.

The first meeting of the new season will be held in October.

WASHINGTON PREPARES YEAR'S PROGRAM

In the Washington Section, two committees work in co-operation with the Governing Committee which has already prepared a tentative program for the new Section year. W. S. James heads the Meetings Committee; Paul B. Lum is chairman of the Membership Committee.

Technical meetings will be resumed in October.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between July 10 and Aug. 9, 1923. The various grades of membership are indicted by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ATKINSON, ROBERT (M) metallurgical engineer, Halcomb Steel Co., *Detroit*, (mail) 8424 Hamilton Boulevard.

BACHMAN, GRAYDON A. (E S) student, University of Minnesota, *Minneapolis*, (mail) 1409 Sixth Street, Southeast.

BAER, WALTER, D. (J) secretary and treasurer, Iron City Spring Co., 2920 Smallman Street, *Pittsburgh*.

BERSIE, HUGH G. (M) engineer, Haskelite Mfg. Corporation, 133 West Washington Street, *Chicago*.

BOLGER, JOHN F. (A) vice-president and sales manager, Allbestos Co., Logan, Philadelphia, (mail) 419 West Upsal Street, *Mount Airy, Philadelphia*.

COLLIER, J. F. (M) manager service, Reo Motor Car Co., Lansing, Mich., (mail) 26 West Warren Avenue, *Detroit*.

CUSHMAN, E. H. (A) automotive engineer and assistant manager, Myron D. Kidder, Inc., *Portland, Me.*, (mail) 343 Forest Avenue.

CUSTER, L. L. (M) president and treasurer, Custer Specialty Co., *Dayton, Ohio*, (mail) 119 Franklin Street.

DURHAM, CADY B. (M) assistant general manager, Buick Motor Co., *Flint, Mich.*, (mail) 301 East Hamilton Avenue.

FREEMAN, F. P. (A) superintendent of motor equipment, Kaufman's Department Stores, Inc., Fifth Avenue, Smithfield and Diamond Streets, *Pittsburgh*.

GARRARD, LESTER A. (J) research engineer, Standard Oil Co. of New York, New York City, (mail) care of Socony, *Manila, P. I.*

GRANER, ADOLF (M) president, Wisconsin Magneto Co., *Milwaukee*, (mail) 824 North Cambridge street.

HANNA, R. W. (J) tool designer, Yellow Sleeve Valve Engine Works, East Moline, Ill., (mail) 1939 Pershing Avenue, *Davenport, Iowa*.

HENDERSON, CHARLES E. (A) purchasing supplies, Air Mail Service, Maywood, Ill., (mail) P. O. Box 6044, Sunny Slope Station, *Kansas City, Mo.*

HILBERT, FAYE W. (A) motor-vehicle inspector, Sinclair Refining Co., *Buffalo*, (mail) 24 Huntington Avenue.

HULING, JOSEPH B. (A) service-station foreman, International Harvester Co., Lagonda Avenue, *Springfield, Ohio*.

KELLER, A. (M) vice-president and works manager, Golde-Patent Mfg. Co., New York City (mail) 30 Gould Avenue, *Long Island City, N. Y.*

KENT, FRANK J. (A) patent lawyer, Cox, Kent & Campbell, 233 Broadway, *New York City*.

KERR, STEPHEN LESTER (E S) student, University of Utah, *Salt Lake City, Utah*, (mail) 153 South 13th East Street.

KINSEY, KENNETH HARRY (J) student, Purdue University, Lafayette, Ind., (mail) *Mentone, Ind.*

LANE, F. J. (A) salesman, Allyne-Zerk Co., Cleveland, (mail) 2681 Lawrence Avenue, *Detroit*.

LEWIS, JOSEPH CARLETON (A) service manager, Noyes Buick Co., 857 Commonwealth Avenue, *Boston*.

MACMILLEN, ROBERT D. (A) director of sales and service, Albert Frank & Co., 14 Stone Street, *New York City*.

MARTY, MATHEW J. (M) engineer, Chicago Mfg. Co., *Chicago*, (mail) 4308 North Monticello Avenue.

MATHEWSON, M. I. (M) experimental and designing engineer, Detroit Gear & Machine Co., *Detroit*, (mail) 670 East Woodbridge Street.

MAXIM, ALBERT (M) engineering mechanic, Ward Motor Vehicle Co., Mount Vernon, N. Y., (mail) 706 Trinity Avenue, *New York City*.

MAYES, W. A. (M) chief engineer, Martin-Parry Corporation, *York, Pa.*

MEAD, RICHARD O. (A) sales manager, American Wood Rim Co., *Onaway, Mich.*

PATTERSON, C. E. (M) works manager in charge of production engineering, Athey Truss Wheel Co., 5631 West 65th Street, *Chicago*.

PATTERSON, C. W. (A) lubricating engineer, Standard Oil Co. of Louisianna, *Memphis, Tenn.*

RANDOLPH, DONALD W. (J) assistant mechanical engineer, Bureau of Standards, *City of Washington*, (mail) 1741 P Street, Northwest.

ROBB, WILLIAM C. (A) assistant manager, Ohio Rubber & Textile Co., 158 Larned Street, West, *Detroit*.

SCHLINGER, W. J. (A) vice-president and general manager, Flint Varnish & Color Works, *Flint, Mich.*

SHEPARD, R. L. (A) metallurgist, Shepard Art Metal Co., *Detroit*, (mail) 141 Montana Avenue, West.

SHIMIZU, YUTARO (A) New York representative, Yanese Automobile Co., Tokyo, Japan, (mail) care of engineering department, Mitsui & Co., 65 Broadway, *New York City*.

SMELLIE, DONALD G. (M) 926 Gilmore Avenue, Northwest, *Canton, Ohio*.

STYRI, HAAKON (M) chief of research laboratory, S. K. F. Industries, Inc., *Philadelphia*.

SULLIVAN, ALAN P. (A) chief engineer, Stackpole Carbon Co., *St. Marys, Pa.*

TEACHOUT, J. HOWARD (M) production manager, White Motor Co., 842 East 79th Street, *Cleveland*.

THOMPSON, SYLVESTER T. (A) secretary and general manager, Duplex Engine Governor Co., Inc., Brooklyn, N. Y., (mail) 3 West 192nd Street, *New York City*.

WALLER, EINAR (M) designing engineer, General Motors Corporation, *Detroit*, (mail) 1704 Meldrum Avenue.

WEADICK, ROBERT M. (J) student, Franklin Institute, Boston, (mail) 366 West Fourth Street, *South Boston*.

WINDLE, E. HOWELL, (E S) student, Ohio State University, *Columbus Ohio*, (mail) 239 Oakland Park Avenue.

ZELKOSKY, J. THEODORE, JR. (E S) student, Stevens Institute of Technology, Hoboken, N. J., (mail) 305 Sixth Street, *West New York, N. J.*

Applicants *for* Membership

The applications for membership received between July 13 and Aug. 15, 1923, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

BANGEL, F. NORMAN, sales, Van Iderstine Co., *Long Island City, N. Y.*

BIRDSELL, ROGER, assistant mechanical engineer, Bureau of Standards, *City of Washington.*

BITTONG, LUDWIG, engineer and machinist, c/o Herman Bittong, Broadway and Court Street, *Elmhurst, N. Y.*

BLACKBURN, ROBERT H., owner, Blackburn Oil Co., *Spartanburg, S. C.*

BRAMAN, GEORGE H., JR., chief draftsman, Walden, Worcester Co., 475 Shrewsbury Street, *Worcester, Mass.*

CHADWICK, LEES W., president, Chadwick-Leclair Co., *Detroit.*

CHANDLER, HENRY, metallurgical engineer, Vanadium Co., *Detroit.*

CHRISTENSEN, ALFRED, mechanical draftsman, Rock Island Arsenal, *Rock Island, Ill.*

CLEGG, LEE M., assistant sales manager, Steel Products Co., *Cleveland.*

COBB, FRANCIS S., president, Seamans & Cobb Co., *Boston.*

DAVIS, JOSEPH ANTHONY, student, Tri-State College, *Angola, Ind.*

DE MEEUS, E., United States representative, Societe O. Englebert Fils & Cie., Liege, Belgium, and superintendent, Medford Woolen Mfg. Co., *Medford, Mass.*

ELLINGHAM, FRANCIS W., manager and chief engineer, Automotive Industries, Inc., *San Jose, Cal.*

FLOYD, A. A., sales engineer, Sheldon Axle & Spring Co., *Wilkes Barre, Pa.*

GROSELLE, JOHN F., automotive engineer, Ordnance Department, Rock Island Arsenal, *Rock Island, Ill.*

HOMAN, A. E., general manager, C. G. Spring Co. of Ohio, *Cleveland.*

HUDSON, RAY M., assistant chief of division, Department of Commerce, *City of Washington.*

JANSSON, AXEL J., designer, International Motor Co., *New York City.*

KASARJIAN, A. A., research engineer, Chalmers plant, Maxwell Motor Corporation, *Detroit.*

KERR, ROBERT H., automotive engineer, Rock Island Arsenal, *Rock Island, Ill.*

LEACH, ALBERT E., manager of drafting room, Studebaker Corporation of America, Piquette Avenue, *Detroit.*

LUDICK, ROY E., aeronautical engineer, Glenn L. Martin Co., 16,800 St. Clair Avenue, *Cleveland.*

LUKS, KRAEMER, engineer on technical staff, American Bureau of Shipping, *New York City.*

LYTLE, THOMAS B., N. Suellenburg & Co., *Philadelphia.*

MAIN, FRANK L., assistant sales manager and experimental engineer, Hayes Wheel Co., *Jackson, Mich.*

MALIN, EDWARD A., general inspector, Gulf Refining Co., *Pittsburgh.*

MCMAHON, JOHN F., mechanical superintendent, Yellow Taxi Corporation, *New York City.*

MILLER, WALTER, manufacturing manager, Marland Refining Co., *Ponca City, Okla.*

MITCHELL, F. A., vice-president, Bristow Co., *Port Townsend, Wash.*

MOORE, PAUL B., *Wrightsville, Pa.*

NYE, NORMAN H., draftsman, F. D. Howe, *Cuyahoga Falls, Ohio.*

O'BRIEN, JOSEPH F., president, Joseph F. O'Brien Mfg. Co., *New York City.*

RAKESTRAW, CLARENCE., instructor, El Paso Public Schools, P. O. Box 1400, *El Paso, Tex.*

RAMSAY, LOUIS, assistant to superintendent, General Electric Co., *Schenectady, N. Y.*

RILEY, JOHN, chief designer, Automatic Gas Producers, Ltd., *Altrincham, England.*

ROBINSON, RICHARD H., student, Tri-State College, *Angola, Ind.*

SCHROEDER, A. F., chief inspector, Falls Motors Corporation, *Sheboygan Falls, Wis.*

SHERMAN, E. A., branch manager, Westinghouse Air Spring Co., *Long Island City, N. Y.*

SHIMER, WILLIAM ROBERT, metallurgical engineer, Bethlehem Steel Co., *Bethlehem, Pa.*

WISCONSIN STEEL CO., 606 South Michigan Avenue, *Chicago.*

ZELKOSKY, J. T., JR., mechanic, 305 Sixth Street, *West New York, N. J.*